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Enhancing Agent Mediated Electronic Markets with Ontology Matching Services and Social Network Support

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Enhancing Agent Mediated Electronic Markets with Ontology Matching Services and Social Network Support

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Resumo

Os Mercados Eletrónicos atingiram uma complexidade e nível de sofisticação tão elevados, que tornaram inadequados os modelos de software convencionais. Estes mercados são caracterizados por serem abertos, dinâmicos e competitivos, e constituídos por várias entidades independentes e heterogéneas.

Tais entidades desempenham os seus papéis de forma autónoma, seguindo os seus objetivos, reagindo às ocorrências do ambiente em que se inserem e interagindo umas com as outras.

Esta realidade levou a que existisse por parte da comunidade científica um especial interesse no estudo da negociação automática executada por agentes de software [Zhang et al., 2011].

No entanto, a diversidade dos atores envolvidos pode levar à existência de diferentes conceptualizações das suas necessidades e capacidades dando origem a incompatibilidades semânticas, que podem prejudicar a negociação e impedir a ocorrência de transações que satisfaçam as partes envolvidas.

Os novos mercados devem, assim, possuir mecanismos que lhes permitam exibir novas capacidades, nomeadamente a capacidade de auxiliar na comunicação entre os diferentes agentes. Pelo que, é defendido neste trabalho que os mercados devem oferecer serviços de ontologias que permitam facilitar a interoperabilidade entre os agentes.

No entanto, os humanos tendem a ser relutantes em aceitar a conceptualização de outros, a não ser que sejam convencidos de que poderão conseguir um bom negócio. Neste contexto, a aplicação e exploração de relações capturadas em redes sociais pode resultar no estabelecimento de relações de confiança entre vendedores e consumidores, e ao mesmo tempo, conduzir a um aumento da eficiência da negociação e consequentemente na satisfação das partes envolvidas.

O sistema AEMOS é uma plataforma de comércio eletrónico baseada em agentes que inclui serviços de ontologias, mais especificamente, serviços de alinhamento de ontologias, incluindo a recomendação de possíveis alinhamentos entre as ontologias dos parceiros de negociação. Este sistema inclui também uma componente baseada numa rede social, que é construída aplicando técnicas de análise de redes socias sobre informação recolhida pelo mercado, e que permite melhorar a recomendação de alinhamentos e auxiliar os agentes na sua escolha.

Neste trabalho são apresentados o desenvolvimento e implementação do sistema AEMOS, mais concretamente:

- É proposto um novo modelo para comércio eletrónico baseado em agentes que disponibiliza serviços de ontologias;

- Adicionalmente propõem-se o uso de redes sociais emergentes para captar e explorar informação sobre relações entre os diferentes parceiros de negócio;
- É definida e implementada uma componente de serviços de ontologias que é capaz de:
    - Sugerir alinhamentos entre ontologias para pares de agentes;
    - Traduzir mensagens escritas de acordo com uma ontologia em mensagens escritas de acordo com outra, utilizando alinhamentos previamente aprovados;
    - Melhorar os seus próprios serviços recorrendo às funcionalidades disponibilizadas pela componente de redes sociais;
- É definida e implementada uma componente de redes sociais que:
    - É capaz de construir e gerir um grafo de relações de proximidade entre agentes, e de relações de adequação de alinhamentos a agentes, tendo em conta os perfis, comportamento e interação dos agentes, bem como a cobertura e utilização dos alinhamentos;
    - Explora e adapta técnicas e algoritmos de análise de redes sociais às várias fases dos processos do mercado eletrónico.

A implementação e experimentação do modelo proposto demonstra como a colaboração entre os diferentes agentes pode ser vantajosa na melhoria do desempenho do sistema e como a inclusão e combinação de serviços de ontologias e redes sociais se reflete na eficiência da negociação de transações e na dinâmica do mercado como um todo.

Palavras-chave: Mercados Eletrónicos Baseados em Agentes; Negociação de Alinhamentos de Ontologias; Redes Sociais Emergentes; Tecnologias de Descoberta de Conhecimento; Sistemas de Apoio à Decisão

Abstract

In electronic commerce, the diversity of the involved actors can lead to different conceptualizations of their needs and capabilities, giving rise to semantic incompatibilities that might hamper negotiations and the fulfilling of satisfactory transactions. In order to provide help in conversation among different actors, markets must offer ontology services to facilitate interoperability.

However, humans tend to be reluctant to accept others' conceptualizations, except if they become convinced that a good deal can be achieved. In this context, the application and exploitation of relationships captured by social networks can result in the establishment of more accurate trust relationships between businesses and customers, as well as the improvement of the negotiation efficiency and therefore the users' satisfaction with the electronic commerce system.

The AEMOS system is an agent-based electronic commerce platform that provides ontology matching services in order to facilitate the interoperability between agents that use different ontologies. AEMOS also includes a social network component that allows improving the ontology alignment recommendations and supporting the agents' decisions about which alignments to select based on the information collected throughout the market and by exploring social network analysis techniques.

This work presents the development and implementation of the AEMOS system, illustrating how the collaboration between the different agents can be helpful in improving the system's performance, and how the inclusion and combination of ontology services and social networks reflects in the efficiency of the negotiation process.

Keywords: Agent Mediated Electronic Commerce; Ontology Alignments Negotiations; Emergent Social Network; Knowledge Discovery Technologies; Decision Support Systems

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Acronyms and Nomenclature

List of Acronyms

ACL	**A**gent **C**ommunication **L**anguage
AI	**A**rtificial **I**ntelligence
AEMOS	**A**gent-based **E**lectronic **M**arket with **O**ntology **S**ervices
AMEC	**A**gent **M**ediated **E**lectronic **C**ommerce
B2B	**B**usiness-to-**B**usiness
B2C	**B**usiness-to-**C**onsumer
C2C	**C**onsumer-to-**C**onsumer
CBB	**C**onsumer **B**uying **B**ehavior
FCT	Science and Technology Foundation (***F****undação para a* ***C****iência e a* ***T****ecnologia*)
FIPA	**F**oundation for **I**ntelligent **P**hysical **A**gents
GECAD	*Knowledge Engineering and Decision Support Research Centre (****G****rupo de investigação em* ***E****ngenharia do* ***C****onhecimento e* ***A****poio à* ***D****ecisão)*
ICL	**I**nter-agent **C**ommunication **L**anguage
ISEM	**I**ntelligent **S**ystem for **E**lectronic **M**arketplaces
JADE	**J**ava **A**gent **DE**velopment **F**ramework
KIF	**K**nowledge **I**nterchange **F**ormat
KQML	**K**nowledge **Q**uery and **M**anipulation **L**anguage
MAFRA	**MA**pping **FRA**mework
MAS	**M**ulti-**A**gent **S**ystems
OA	**O**ntology **A**gent
OAA	**O**pen **A**gent **A**rchitecture
Prolog	***Pro****grammation en* ***Log****ique*
SBO	**S**emantic **B**ridging **O**ntology
SN	**S**ocial **N**etwork
SNA	**S**ocial **N**etwork **A**nalysis
SNS	**S**ocial **N**etwork **S**ites

Nomenclature

a	First agent, or buyer agent depending on the context
aa	Adequacy of an ontology alignment to a pair of agents
acceptanceLevel	Alignment's acceptance level for an agent
alce	Set of ontology's entities that are covered in an alignment
alignmentUtil	Utility value of an alignment for an agent
alignmentUtilForNeg	Utility value of an alignment for a business negotiation
ataa	Alignment-to-agent adequacy value
atar	Agent-to-agent relationship value
atbc	Alignment-to-business-negotiation confidence value
b	Second agent, or seller agent depending on the context
c_i	An agent that has previous negotiations with both negotiating partners, or one of the agents closest to an agent
cov	Alignment's coverage of an agent's valued ontologies' entities
cp	Set of ontology's entities both relevant to an agent and covered in an alignment
cp_i	Ontology's entity that is simultaneously valued by an agent and covered in an alignment
cpSim	Similarity value of continuous properties
credibilityPer	The percent that a business agent should fade (or increase) on an alignment's score if the number of negotiations where it was used is lower than its minimum defined
dfpSim	Similarity value of a discrete functional property
dnfpSim	Similarity value of a non-functional discrete property
d_{pp}	Description of a proposed product
d_{pp_i}	Value of an attribute from a proposed product's description
d_{pr}	Description of a desired product
d_{pr_i}	Value of an attribute from a requested product's description
f_i	Evaluation factor
fn	Number of failed negotiations
m	Ontology alignment (formally referred to as ontology mapping)
max(p)	Maximum limit for property *p*

mce	Coverage of an alignment according to a requested product's description
min(p)	Minimum limit for property *p*
minNumNegs	Minimum number of business negotiations where an alignment was used to consider credible its adequacy evaluation
minScore	Minimum score to consider an alignment acceptable
numNegs	Number of previous business negotiations where an alignment was used
ncp	Set of ontology's entities which are relevant to an agent but not covered in an alignment
ncp_j	Ontology's entity that is valued by an agent but is not covered in an alignment
p	Evaluated property
p(a)	Values of the property *p* for agent *a*
p(b)	Values of the property *p* for agent *b*
$pc(p_r)$	Set of ontology's entities used to describe a product
pc(m)	Set of ontology's entities covered in an alignment
pdue	Set of ontology's entities used in the description of a requested product
p_p	Purchased product
ppUtil	Utility value of a product proposal for a buyer agent
pSim	Similarity of agents' profiles and valued ontologies' entities
p_r	Desired product
rp	Information about the relevance attributed by an agent to ontology's entities
rae	Adequacy of an alignment to the agents closest to an agent
r_{pr}	Information about a desired product's properties' relevance
r_{pr_i}	Relevance value of a property
sa	Satisfaction in closed deals involving an alignment
sat	Satisfaction of B agent about the purchased products from a S agent
sata	Agent's satisfaction in closed deals using an alignment
$simF_i$	Method used to determine the similarity between two values
sn	Number of successful negotiations

sniScore	Score attributed by a SN-i agent to an alignment
sra	Success rate in business negotiations while using an alignment
srn	Success rate on previous negotiations between two agents
srna	Agent’s success rate in business negotiations using an alignment
srnSim	Similarity of two agents’ interactions with other agents
srnS	Similarity of two agents’ interactions with other agent
tn	Total number of negotiations
$\boldsymbol{w_i}$	First weight
$\boldsymbol{w_j}$	Second weight

1 Introduction

1.1 Introduction

The growth of electronic commerce has increased the demand for automated processes to support both customers and suppliers in buying and selling products [Huang et al., 2010]. In this context the automated negotiation carried by software agents has been receiving an increasing attention [Zhang et al., 2011].

In an efficient agent-mediated electronic market, where all the partners, both sending and receiving messages have to lead to acceptable and meaningful agreements, it is necessary to have common standards, like an interaction protocol to achieve deals, a language for describing the messages' content and ontologies for describing the domain's knowledge [Hepp, 2008] [Fensel et al., 2001] [Obrst et al., 2003]. The need for these standards emerges due to the nature of the goods/services traded in business transactions. The goods/services are described through multiple attributes (e.g. price, features and quality), which imply that the negotiation processes and final agreements between consumers and suppliers must be enhanced with the capability to both understand the terms and conditions of the transaction (e.g. vocabulary semantics, currencies to denote different prices, different units to represent measures or mutual dependencies of products). This is referred to as the ontology dimension of the business transactions.

However, in electronic commerce, the diversity of the involved actors can lead to different conceptualizations of their needs and capabilities, giving rise to semantic incompatibilities that might hamper the negotiation and prevent the fulfilling of satisfactory transactions. In order to provide help in the conversation among different agents, the electronic commerce system must provide ontology services, more specifically, ontology matching services.

On the other hand, humans tend to be reluctant to accept other's conceptualizations. For that they must be convinced that a good deal can be achieved. In this context, the application and exploitation of relationships captured by social networks can result in the establishment of more accurate trust relationships between businesses and customers, as well as the improvement of the negotiation efficiency and therefore the users' satisfaction with the electronic commerce system.

Despite the diversity of studies in this area, there is a lack of solutions that address all the relevant aspects in a comprehensive manner. Most approaches tend to focus on a determined aspect of the problem adopting simplistic (and unrealistic) solutions, or simply ignoring the remaining aspects.

In order to resolve this gap, the AEMOS system, an innovative project (PTDC/EIA-EIA/104752/2008) supported by the Portuguese Agency for Scientific Research (FCT), is being developed. The AEMOS (Agent-based Electronic Market with Ontology Services) system [Silva et al., 2009], is a multi-agent system for electronic commerce, which proposes an ontology-based information integration approach, exploiting the ontology matching paradigm, by aligning consumer needs and the market capacities, in a semi-automatic mode, improved by the application and exploitation of the relationships captured by the social networks.

1.2 Main Goals

In the context of the AEMOS project this work aims at the development and implementation of a multi-agent model for electronic commerce that provides ontology services and social network support, demonstrating how the exploitation of the ontology matching paradigm and social networks allows increasing the efficiency of communication/negotiation between agents.

More specifically, this work aims at:

- Proposing a system model for Agent Mediated Electronic Commerce (AMEC) where ontology services are provided, improved by the application and exploitation of the users' relationships information captured by the social networks; Which includes:
    - Identifying the way agents access an ontology service;
    - Identifying the requirements to incorporate a social network component;
- Exploiting and adapting Social Network Analysis methods and algorithms to the different stages of the marketplace processes, namely ontology alignment negotiation and business negotiation.

1.3 Main Contributions

This work presents the development and implementation of the AEMOS system, illustrating how the collaboration between the different agents can be helpful in improving the system's performance, and how the inclusion and combination of ontology services and social networks reflects in the efficiency of the business negotiation process.

With this work a new Agent Mediated Electronic Commerce model is achieved, which provides:

- Ontology matching services, enabling the interoperability between heterogeneous agents;
- Social network support, allowing improving the ontology services performance as well as supporting agents with their decisions about which ontology alignment to choose.

A model and implementation are proposed for an ontology matching services component that:

- Is able to suggest alignments between ontologies for pairs of agents;
- Is able to, by using an ontology alignment previously approved, translate messages written according to an ontology to messages written according to another ontology;
- Is able to enhance its own services by using the social networks support.

A model and implementation are proposed for a social networks component that:

- Is capable of building/manage a graph representing proximity relationships between agents, by taking into account their profiles, behavior and interactions;
- Exploits and adapts Social Network Analysis methods and algorithms to the different stages of the marketplace.

Through experimentation it is demonstrated how the presented model can improve the efficiency of a business negotiation.

The work developed in the scope of this thesis was supported by the AEMOS project (PTDC/EIA-EIA/104752/2008), funded by FCT “Fundação para a Ciência e a Tecnologia”, under the scope of the Knowledge Engineering and Decision Support research Centre – GECAD.

Additionally, throughout the development of this work, some scientific papers were published, concerning the scientific advances achieved by the developed work:

- Maria João Viamonte, Nuno Silva, Paulo Maio, “Agent-Based Simulation of Electronic Marketplaces with Ontology Services”, in *The 23rd European Modeling & Simulation Symposium (Simulation in Industry)*, EMSS 2011 [Viamonte et al., 2011]. This paper presents the multi-agent model and the ontology services of the AEMOS system.
- Maria João Viamonte, Virgínia Nascimento, Nuno Silva, Paulo Maio, “AEMOS: An Agent-Based Electronic Market Simulator With Ontology-Services And Social Network Support”, in *The 24th European Modeling & Simulation Symposium (Simulation in Industry)*, EMSS 2012 [Viamonte et al., 2012]. This paper presents the proposed models for the AEMOS system’s ontology services and social network component.
- Virgínia Nascimento, Alda Canito, Maria João Viamonte, Nuno Silva, “Enhancing ontology alignment recommendation by exploiting emergent social networks”, in *The 2012 IEEE/WIC/ACM International Conference on Intelligent Agent Technology*, WI-

IAT'2012 [Nascimento et al., 2012]. This paper presents the model, implementation and experimentation of the AEMOS system's social network component.

1.4 Document Structure

This thesis is composed of six chapters, organized as follows:

In this first chapter, a brief description of this work is presented, including its motivations, main goals and contributions.

Chapter 2 presents the background of this work, i.e., the current state of the technologies which are relevant in the scope of this thesis, introducing concepts that are important for understanding the problem and the proposed solution.

In chapter 3 the proposed model for the AEMOS system is presented, detailing its multi-agent model, interaction protocols and main actors.

Chapter 4 details the proposed models for the ontology services and for the social network support component.

Chapter 5 illustrates the interface of the AEMOS system and presents a case study for the presented models.

Chapter 6 contains the most important conclusions and future work based on the system's current limitations and new features.

2 Background

2.1 Introduction

Electronic commerce (also referred to as e-commerce) is a widely used technology with an increasing popularity in today's business [Du et al., 2005]. This type of commerce presents several advantages when compared to the traditional commerce. For instance, the information becomes more easily accessible which gives customers the ability to compare several products from various stores in a more convenient and comfortable way. Moreover, by selling directly to customers or reducing the number of intermediaries, suppliers can achieve higher profits while charging lower prices [Laudon and Laudon, 2000].

However the amount of available information in e-commerce also becomes a problem, being difficult for a human user to compare all possible deals in order to achieve the best one. Intelligent agents present characteristics that make them a powerful tool to overcome this, and some other, problems of e-commerce, assisting either consumers or suppliers in the search for the deal that best meets their interests.

Despite the considerable level of research on this area, the level of automation achieved is still limited. As stated in [Cui-Mei, 2009], this is probably due to the fact that the information existent on the web is mainly represented for human comprehension only. In order to overcome this problem, ontology centered approaches have been proposed, where the content is represented according to an explicit, formal, shared conceptualization, i.e. an ontology [Qin et al., 2009] [Mei et al., 2009] [Cao et al., 2009]. However, the diversity of the involved actors can lead to different conceptualizations of their needs and capabilities giving rise to semantic incompatibilities that might hamper negotiations and the fulfilling of satisfactory transactions. The ontology matching paradigm [Euzenat and Shvaiko, 2007], which can be defined as the process of discovering correspondences between ontologies, that can be used to transform messages written according to one ontology in messages written according to the other, is presented as a possible solution for this problem.

On the other hand, humans tend to be reluctant to accept others conceptualizations. For that they must be convinced that a good deal can be achieved. In this context, the observation of the market activity, and the detection of emergent relationships between the participants, can lead to the establishment of more accurate trust relations between participants as well as the improvement of the negotiation efficiency and therefore the users' satisfaction with the system.

In order to better understand the scope of this thesis, as well as the proposed solution, the relevant concepts are introduced in the following subsections.

2.2 Electronic Commerce

As defined in [Till, 1998], electronic commerce covers any form of administrative or business transaction, or information exchange that is executed using some information or communication technologies.

According to this definition, e-commerce includes innumerous activities that can be executed using several technologies. In this work this definition is restricted, being considered only the commercial activities executed through the Internet.

There are several types of e-commerce which are mainly characterized by the type of its participants. The most common are the Business-to-Business (B2B) and Business-to-Consumer (B2C) e-commerce, where Business refers to an organization (company) and Consumer to an individual consumer (normally a person). Other examples are, the increasingly popular Consumer-to-Consumer (C2C) e-commerce, and, the less common, Nonbusiness e-commerce (also known as no-business e-commerce) and Intra-business e-commerce [He et al., 2003] [Xiao-fang and Ying, 2006].

2.2.1 Electronic Markets

According to Bakos [Bakos, 1998] an electronic market is a virtual place, where the participants on a specific business area, which are geographically distributed and are possibly unaware of each other, meet in order to achieve a common business goal.

Despite this difference in environment (which is virtual) and used technologies, there are some characteristics that are common to any kind of market, electronic or not.

For example, the same author [Bakos, 1998] defends that any kind of market, should grant three main functionalities, namely:

- Enable the meeting of the different participants;
- Facilitate the exchange of information, goods, services and payments;
- Provide an institutional infrastructure responsible for the establishment of behavior and business rules.

Economically speaking, the markets can be classified as monopolists or competitive [Varian, 1980]. In the first case a determinate product or service is provided solely by one supplier, whereas in the second case, the same product or service can be provided by multiple suppliers. In competitive markets the consumers typically choose the supplier that provides the required product or service at the lowest price.

Normally the main players on a market are the consumers and suppliers. However, most markets include other entities called intermediaries. The intermediaries are normally included in order to increase the efficiency of the transactions. These can be classified according to their functions [Viamonte, 2004]:

- Managers – responsible for the storage of information about the market's current capabilities (i.e. the registered suppliers, the available products or services) to be consulted by the consumers;
- Centralizers – entities that work like some sort of "blackboard" where the consumers register their requests and the suppliers search for requests that they might be able to satisfy;
- Mediators – entities that assume the function of the consumers or suppliers acting on their behalf. It acts as an intermediary in the negotiation process protecting the privacy of the consumer or supplier it represents.

A market can also be classified according to the existence, or not, of a limited amount of time for its activity. Finite markets are those in which a deadline is defined for its activity.

2.2.2 Consumer Buying Behavior Model

A business transaction life cycle is normally divided in three phases [Schmid, 1994] [Klein, 1994]:

- Information phase – which may include the identification of the needs, the search of products and the search of suppliers;
- Negotiation phase;
- Resolution phase – which normally includes the payment and delivery, and the service evaluation.

These phases are captured and complemented in the Consumer Buying Behavior (CBB) model [Runyon and Stewart, 1987] which represents the usual behavior of a typical consumer in a B2C e-commerce context. The modeled behavior is illustrated in Figure 1 (below).

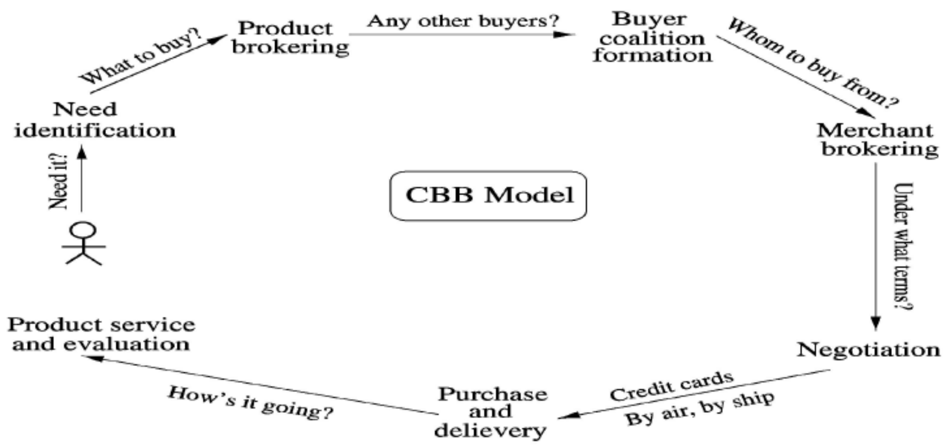

Figure 1 – Illustration of the CBB Model [He et al., 2003]

The model divides the typical behavior of a consumer in seven phases:

- Need Identification – The consumer recognizes the need to acquire a product or service;
- Product Brokering – The consumer determines which product to buy in order to satisfy its needs;
- Buyer Coalition Formation – After determining the product to buy, the consumer may try to form a coalition with other consumers in order to take advantage of buying in bulk;
- Merchant Brokering – In this step, the consumer (or buyers coalition's leader) chooses the supplier from which to obtain the desired product;
- Negotiation – After choosing a supplier, the next step is the negotiation of the terms and conditions for the transaction;
- Purchase and delivery – At this step the payment and delivery methods are chosen;
- Product service and evaluation – Finally, the transaction is executed and the consumer performs evaluation.

2.3 Agent-based Systems

During the 80's a new field, the Distributed Artificial Intelligence, emerged resultant from the merging of Artificial Intelligence (AI) and Distributed Computation. According to Davis [Davis, 1980], the Distributed Artificial Intelligence was created with the purpose of solving problems for which a single entity equipped with AI could not provide the best response.

The Multi-Agent Systems (MAS) emerged as a part of the Distributed Artificial Intelligence, where the focus is on the coordination of the intelligent behaviors shown by a community of agents (autonomous or semi-autonomous) in such a way that they will be able to share knowledge, abilities, goals and plans in order to take actions or solve problems. Moreover, individual agents should be able to reason about the coordination processes involved.

2.3.1 Software Agent

A common accepted definition for the term "Agent" determines that an agent is a computer system situated in some environment in order to meet its design objectives [Wooldridge, 2002]. However, there is no universally accepted agreement for a definition of the concept, probably because each definition grew directly out of the application area the definer had in mind [Huang et al., 2009].

There is, however, a consensus about some of the characteristics an agent should possess. Agents can be classified according to a set of characteristics they present. Among these characteristics are [Weiss, 2010]:

- Sensorial capability – the agent has sensors to gather information about its environment;
- Reactivity – the agent feels and acts, reacting to on-going environment changes;
- Autonomy – the agent decides and controls its own actions;
- Pro-activity – the agent is goal driven, goes beyond reacting to the environment;
- Persistency – the agent exists during long periods of time;
- Social skills – the agent communicates and co-operates with other agents or even people, e.g. competes or negotiates;
- Learning – the agent is able to change its behavior based on prior experience;
- Mobility – the agent is able to move from one machine to another;
- Flexibility – the agent's tasks don't need to be pre-determined;
- Agility – the agent has the ability to swiftly take advantage of new unforeseen opportunities;
- Character – the agent has a credible personality and emotional behavior;
- Intelligence – the agent has the ability to reason autonomously, to plan its actions, to correct its mistakes, to react to unexpected situations, to adapt and to learn.

Some authors [Cui-Mei, 2009] [Huang et al., 2010] also defend that agents should possess other characteristics such as:

- Personalization – ability to represent an entity's information and behavior;
- Rationality – an agent's mental property that attract it to maximize its achievement and to try to achieve its goals successfully;
- Veracity – or honesty, mental property that prevents an agent from knowingly communicate false information;
- Sanity – mental property that ensures that the agent only takes actions helpful to achieve its goals, and doesn't take them blindly.

Although these characteristics may derive from the previously presented, like the character or intelligence, characteristics like personalization, rationality and honesty are crucial in B2C e-commerce applications.

2.3.2 Multi-Agent Systems

Agents can be useful as stand-alone entities that perform some tasks delegated by an user [Cui-Mei, 2009] freeing the user from some laborious work. However, in most cases agents exist in environments that contain other agents, normally interacting with each other, constituting multi-agent systems (MAS).

MAS present several advantages over isolated agents, such as reliability, robustness, modularity, scalability, adaptability, concurrency, parallelism, and dynamism [Elamy, 2005].

However, when agents need to interact with each other some common norms become necessary, such as [Viamonte, 2004]:

- A communication platform, which includes the interaction protocol to reach deals;
- A communication language, i.e., a language to describe the messages' content;
- An ontology, i.e., a vocabulary and semantics to describe the domain knowledge.

Normally, in order to be able to interact the agents should use the same communication language and ontology. They should also be able to communicate when using different but translatable (or overlapping) ontologies, in this case the MAS should be prepared to support this kind of communication.

On the other hand, in order to be efficient, the communication platform should include several services, such as:

- Communication Services – which includes the message exchange mechanism (Point-to-Point, Group, Broadcast, Blackboard), synchronism, pooling, forwarding;
- Security Services – which includes names services, message encryption services and permissions services;
- Information or Directory Services – including White and Yellow pages services, normally corresponding to Facilitator or Broker agents;
- Conversation Services – including time-out mechanisms, information management and synchronization.

The need for these norms and their requirements turn the development of a MAS into a very complex and laborious process. In order to facilitate and improve the development and deployment of a MAS there are some platforms that already provide the basic MAS requirements allowing the developer to focus on the particular issues of their studies.

2.3.3 MAS Development Platforms

A MAS development platform normally provides the required communication platform services facilitating the development of agents that can communicate with each other.

Currently there are several ways of implementing the communication platform services, mainly depending on the desired interaction protocol (i.e. message exchange mechanism), and there are several communication languages and formats (e.g. KIF, KQML, ACL, ICL), giving rise to different MAS architectures and, consequently different MAS development platforms. Two examples of MAS development platforms are JADE and OAA.

JADE (Java Agent DEvelopment Framework) [JADE, 2000] is presented as "an enabling technology, a middleware for the development and run-time execution of peer-to-peer applications which are based on the agents paradigm" [Bellifemine et al., 2003]. JADE was developed with the main goal of creating a standard, following FIPA [FIPA, 1996] specifications, so that the MAS could be more easily extensible and compatible with other MAS. JADE allows reducing the effort demanded to develop MAS that complies with FIPA specifications. It is developed in Java [Java, 1995] and allows the communication between agents running in different platforms (i.e. Operative Systems), as long as they are developed in Java as well. In JADE agents communicate using the language FIPA-ACL (Agent Communication Language) [FIPA, 2002a] which is constituted by three components:

- Communication language, normally in KQML (Knowledge Query and Manipulation Language) format, which is a protocol for the exchange of information and knowledge between agents. It is a declarative language and has three layers: (i) content, which is an expression in an agreed format (for example KIF); (ii) message, which expresses the communication logic, stating the language used to convey the content (i.e. ontology), the type of content expression; and (iii) communication, which defines how communication will be established, says who is the sender and the receiver, the type of communication, and other related details;
- Formalism, normally KIF (Knowledge Interchange Format) format, which denotes a computational formalism for knowledge exchange between programs. It has a declarative semantics and supports the interpretation of expressions which are formulated in terms of First Order Predicates Logic;
- Ontology which defines the set of classes, function and alphabet that applies to a determined domain or universe of discourse, to which is associated an axiomatic that allows interpreting the exchanged messages.

On the other hand, OAA (Open Agent Architecture) [OAA, s.d.] is described as "a framework for building flexible, dynamic communities of distributed software agents". This platform was developed with the main goal of integrating a heterogeneous community of software agents, in a distributed environment. This platform allows achieving the dynamic and extensive nature of blackboard based systems, the efficiency of mobile objects and the dynamic resultant from the agents' interactions. In OAA the agents communicate using the ICL (Inter-agent Communication Language) language. ICL is based on an extension of the Prolog[1] language and uses its syntax. This language includes a communication protocol layer that assumes a similar role of the KQML's communication layer, and a content layer similar to the

[1] http://en.wikipedia.org/wiki/Prolog

one provided in KIF format. The ICL's communication layer is defined by the event types and their associated parameters lists. The content layer consists on the specific goals, triggers and the data elements that can be embedded with the various events.

JADE authors defend that a peer-to-peer architecture allows reducing situations of failure that are frequent in systems that rely on a single entity. OAA systems rely on the Facilitator agent which can be seen as single point of failure; however it is possible to introduce multiple Facilitators reducing this problem. Moreover, OAA platform allows developing completely heterogeneous systems where agents can be developed using the programming language that best suits their tasks. One the other hand, OAA also considers the possibility of including humans as agents, being the ICL language originally specified with the purpose of simplifying the Natural Language processing[2].

2.4 Agent Mediated Electronic Commerce

By analyzing the CBB model (cf. Section 2.2.2), the roles that software agents can play as mediators in e-commerce systems, can be identified. Their great level of autonomy, personalization and sophistication make them strong candidates to represent the consumers' behavior, being able to perform tasks which involve collecting and filtering information, personalized evaluations and complex coordination [Viamonte, 2004].

Research in Agent Mediated Electronic Commerce (AMEC) has been pursued in different fields of knowledge, such as game theory, social sciences and artificial intelligence. Each field has concentrated on different aspects of the agent interactions, making the pertinent assumptions for the goal of their study. The literature in negotiation agents gives an important support to develop and implement AMEC systems [Lomuscio et al., 2001] [Jennings et al., 2001] [Sandholm and Vulkan, 1999] [Krovi et al., 1999].

The use of intelligent agents in electronic commerce systems provides several benefits, for example [Zhang et al., 2011]:

- Allows reducing human work, freeing human user of laborious tasks;
- Allows saving time and money, normally agents are faster than humans;
- Enable better pricing, emotion-free automated agents can negotiate more rationally than humans and may find more optimal contracts.

Having these benefits in mind the e-commerce sites increasingly incorporate agent-based systems for providing goods and services to their customers [Mohanty and Passi, 2010].

Intelligent agents have several applications in e-commerce systems [Huang et al., 2010], normally they are related with the search/filtering of information in order to support the user in finding the product that best fulfils its preferences. Many electronic marketplaces,

[2] http://en.wikipedia.org/wiki/Natural_language_processing

especially in the B2C, are in essence some kind of search engine where consumers look for the best product in a database of products offered by suppliers [Huang et al., 2009]. For example, Mohanty and Passi [Mohanty and Passi, 2010] present an agent-based e-commerce system that recommends products to consumers based on their preferences. This system focus on supporting consumers with the product discovery ignoring the other stages related to a business transaction.

However, despite the amount of research in this area, the level of automation achieved is still limited. Most studies have not paid attention and focus to one of the most significant parts of a business transaction: negotiation [Ateib, 2010]. Despite the negotiation capabilities are essential in B2C e-commerce systems, negotiation is a time-consuming process because all parties desire to maximize their own payoff while they may have opposite goals. The use of software agents to represent the negotiating parties could greatly decrease efforts and the time needed to complete negotiations [Huang et al., 2009].

Currently, there are some studies that address the negotiation phase, however in most of them agents are created having price has the sole criterion neglecting other characteristics that may define the benefit of the product for the consumer (e.g. delivery time or warranty). In [Huang et al., 2009] a multiple-attribute negotiation model for B2C e-commerce is presented, which deploys intelligent agents to facilitate autonomous and automatic negotiation between buyers and sellers agents, for on-line buying and selling, while quickly responding to consumers. This model includes four phases: (i) information collection, (ii) search, (iii) negotiation and (iv) evaluation.

Moreover, only a few studies consider the semantic incompatibilities problem (e.g. [Cui-Mei, 2009] [Viamonte, 2004] [Qin et al., 2009]) and even those do not provide solutions strong enough to be applied in real situations.

2.4.1 ISEM

ISEM (Intelligent System for Electronic Marketplaces) [Viamonte, 2004] [Viamonte et al., 2006] is an agent-based electronic marketplace simulator, designed for the analysis of agents' market strategies. ISEM provides a rich set of behavior parameters that allows capturing the complexity of a consumer's behavior. It also provides existing information about the market allowing suppliers to make assumptions about the consumers' behavior and preferences. The agents adapt their behavior to the user's preference model and business strategies.

ISEM aims at studying e-commerce in B2C context. The B2C, is oriented to the individual consumer, and, as pointed out in [Huang et al., 2009], is becoming more widespread as more people come to recognize its convenience and its ability to rapidly respond to requests as more products and services become available.

The ISEM was developed for competitive marketplaces, where multiple suppliers provide a determined product, and consumers typically choose the supplier that provides the desired product (and the desired quality) at the lowest price. The markets are also finite, i.e., each consumer or supplier has a deadline to acquire/sell each product.

In ISEM the consumer behavior is modeled according to the CBB model (cf. Section 2.2.2). However, the two final phases of the model (Purchase and Delivery, and Product service and Evaluation) are not contemplated.

The system includes a complex simulation infrastructure, able to cope with the diverse time scales of the supported negotiation mechanisms and with several players competing and cooperating with each other. In each situation, agents dynamically adapt their strategies, according to the present context and using the dynamically updated detained knowledge [Viamonte et al., 2006].

ISEM is very flexible as it is possible to define the model to simulate, including the number of agents, each agent's type and strategies.

2.4.1.1 The Multi-agent Model

ISEM is developed using the OAA platform and agents communicate by using the ICL language.

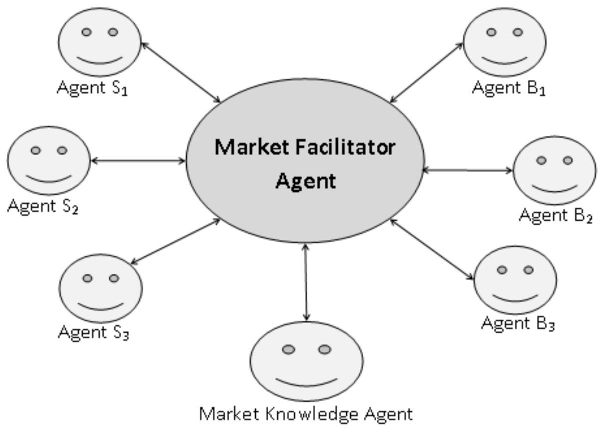

Figure 2 – ISEM's Electronic Market (adapted from [Viamonte, 2004])

As illustrated in Figure 2, ISEM's multi-agent model is composed by four types of agents:

- Buyers (B) – which are agents representing consumers. Normally several B agents exist per marketplace;
- Sellers (S) – which are agents representing suppliers. Normally various S agents exist per marketplace;
- Market Facilitator (MF) agent – which coordinates the simulated market and ensures that it functions correctly. It knows the identities of all the agents in the market, regulates negotiation, and assures that the market operates according to established rules. Normally only one MF exists per marketplace;
- Market Knowledge Agent – which collects information about the market, extracts knowledge from the collected information, and provides information about the market when requested by other agents.

2.4.1.2 The Interaction Protocol

ISEM assumes the existence of a global ontology, i.e., a single ontology is used by all agents in the market. In order to be able to participate in the market, B and S agents must first register using the required ontology to describe their products and preferences.

The negotiation protocol used in ISEM, as illustrated in Figure 3 (below), is bilateral contracting, based on FIPA's "Iterated Contract Net Interaction Protocol Specification" [FIPA, 2002b], where B agents are looking for S agents that can provide them with the desired products at the best conditions.

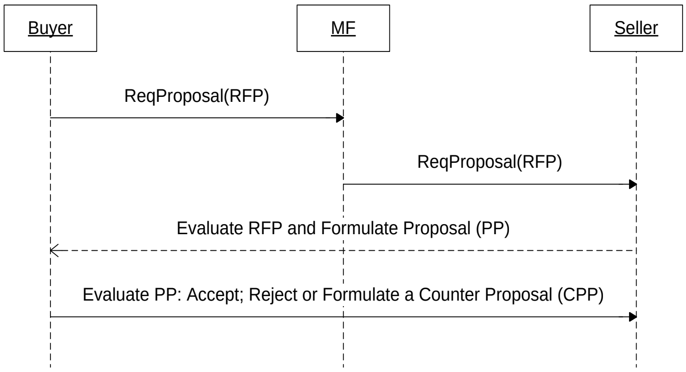

Figure 3 – ISEM's Bilateral Contract Protocol

Negotiation starts when a B agent sends a request for proposal (RFP), cf. Figure 3 and Figure 4. In response, a S agent analyses its own capabilities, current availability, and past experiences and formulates a proposal (PP).

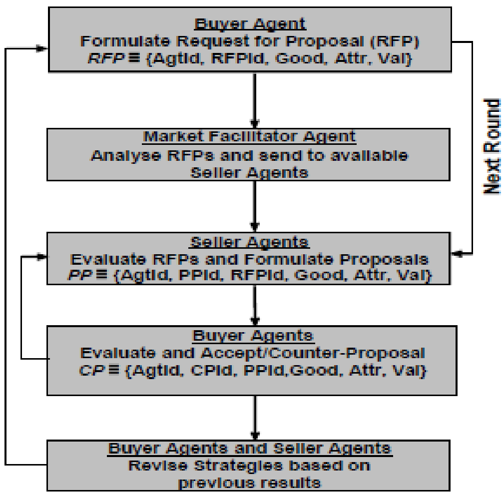

Figure 4 – Sequence of Bilateral Contracts [Viamonte et al., 2006]

S agents can formulate two kinds of proposals: (i) a proposal for the product requested or (ii) a proposal for a related product, according to the B agent's preference model. On the basis of the bilateral agreements made among market players and lessons learned from previous bid rounds, both agents revise their strategies for the next negotiation round and update their individual knowledge module.

2.4.1.3 Limitations

ISEM was developed with the goal of studying agents' market strategies and, therefore, other aspects relevant to AMEC systems are avoided.

One of these aspects is the semantic heterogeneity which occurs when the market agents use different ontologies to register their needs and capabilities. In order to be able to participate in ISEM, all agents must adopt a single ontology: the market ontology provided by ISEM, forcing the agents to change the way they represent their knowledge.

2.5 Semantic Incompatibilities

In e-commerce, especially in B2C, the diversity of the involved actors can lead to different conceptualizations of their needs and capabilities giving rise to semantic incompatibilities.

In general, current approaches for AMEC systems consider simplified and limited solutions to deal with semantic problems. Some consider the existence of an agreed ontology, which means that agents can only negotiate if they adopt the same ontology [Cui-Mei, 2009]. Other develop and use their own ontology, such that to participate in the market each agent has to adopt this ontology [Viamonte, 2004] [Qin et al., 2009].

These approaches allow avoiding interoperability issues, although they are simplistic and unrealistic alternatives that reduce the systems flexibility [Saad et al., 2008].

Normally, in such open environments, as the e-commerce, each agent has its own specific ontology to describe their universe of discourse, their needs and their capabilities, giving rise to a (semantic) heterogeneity problem that is seen as a corner stone for agents' interoperability.

FIPA [FIPA, 1996] has analyzed the interoperability problem in heterogeneous MAS and has proposed an Ontology Agent (OA) for MAS platforms [FIPA, 2001]. Among other responsibilities, the OA may provide the translation service of expressions between different ontologies or different content languages by itself, possibly as a wrapper to an ontology server.

This translation service may be achieved by exploiting the ontology matching paradigm [Euzenat and Shvaiko, 2007].

2.5.1 Ontology

"Ontology is an explicit specification of a conceptualization" [Gruber, 1993].

Despite its few words this is the most common definition of ontology and the one closest to a consensus, where, according to [Studer et al., 1998]:

- “Conceptualization” means a domain’s abstract and rational model which includes the identification and description of concepts, properties and relations between them;
- “Specification” mean the detailed, accurate, consistent, solid and meaningful description of a domain;
- “Explicit” means the representation of the conceptualization in a way that agents can understand.

Brost [Brost, 1997] proposed a modification to this definition adding two new characteristics: “formal” and “shared”, emerging the definition “Ontology is a formal and shared specification of a conceptualization”, also with great level of acceptance. In this definition:

- “Formal” means that either humans or machines are able to read, understand and process the ontology;
- “Shared” means that the ontology is accepted in a consensus by a group, and not only by an individual.

2.5.2 Ontology Matching

Ontology matching [Euzenat and Shvaiko, 2007] can be described as the process of discovering semantic relations (i.e. correspondences) between the concepts and properties of two ontologies.

The ontology matching is a non trivial process which requires a deep knowledge about the conceptualizations behind both ontologies and their semantic similarities. Determining correspondences between ontologies’ entities (i.e. concepts or properties) is a naturally ambiguous and subjective process. According to [Martins, 2008], during this process, it is frequent to occur some ambiguous situations where:

- Entities with the same meaning have different names;
- Entities with the same name have different meanings;
- Terms with the same meaning are written differently;
- An entity from a source ontology may correspond to more than one entity from the target ontology;
- More than one entity from the source ontology corresponds to one from the target ontology.

The ontology matching process can be performed (i) manually, where a domain expert determines the correspondences between the ontologies; (ii) in a semi-automatic way, where the domain expert is supported by automatic ontology matching techniques; or (iii) in a completely automatic way, where the process if performed by using unsupervised automatic ontology matching techniques.

The result from the ontology matching process consists on a document containing the semantic relations between the entities from the source ontology and the target ontology. This document is denominated ontology alignment.
Since the manual, or even semi-automatic, ontology matching may turn into a very complex and laborious process, aggravated with the size of the ontologies, the automatic approach may seem like the best solution. However, caution is needed when using this kind of technology which due to its low level of maturity and the complexity of the process, often results in inaccurate alignments.

2.5.3 MAFRA Toolkit

MAFRA (Mapping FRAmework) Toolkit [Maedche et al., 2002] is an ontology matching and data transformation tool, which enables the identification, specification and representation of semantic relations between entities of two ontologies (i.e. source and target ontologies), and the application of these relations in the translation of instances from the source ontology into instances from the target ontology.

In the MAFRA Toolkit an ontology alignment is described using the SBO (Semantic Bridging Ontology) ontology, which specify, classify and describe the types of relations in the ontology alignments, inter-relate them and provide other necessary modeling functionalities (i.e. constructs) [Martins, 2008].

2.6 Social Network Analysis and Trust-based Recommendations

In e-commerce the personal contact between the participants, which allows them to make assumptions about each other, is lost. However, e-commerce allows a better observation of the market activity, including the participants' behavior and their interactions. This possibility enables the application of knowledge discovery technologies which may be used to assist either consumers or suppliers in their tasks.

Through the analysis of the participants' information and interactions it is possible to capture relationships between them forming a Social Network (SN). This information can lead to the establishment of more accurate trust relations between agents as well as the improvement of the negotiations' efficiency and therefore the users' satisfaction with the system.

A SN consists of a set of relations that represent not only the presence, or absence, of a relationship between actors, but also its weigh or intensity [Handcock et al., 2007]. The use of this technology is increasing mainly due to the increasing popularity of the Social Network Sites (SNS) which consists of web places where registered users may give information about themselves, their preferences, their tastes and, most importantly, their relations with other users. Some examples of these sites are Facebook[3], LinkedIn[4], Hi5[5], etc.

The analysis of SN has diverse applications in e-commerce systems, among them are:

- Detecting malicious or unreliable users, which are frequent on the internet due to anonymity and the possibility of creating multiple accounts [Jyun-Cheng and Chui-Chen, 2008];
- Recommending products in which consumers might be interested, taking into account their preferences, previous purchases and recommendations made by consumers with similar preferences or with a high level of influence on the social network [Zhou, 2009] [Yu and Wang, 2010];
- Detecting groups of consumers or suppliers with similar interests in order to support the formation of buyer coalitions or the creation of virtual enterprises;
- Performing market studies.

This knowledge allows the improvement of the market's functioning by supporting agents on their decisions.

2.6.1 Building a Social Network

Each relationship in a SN has a meaning which varies depending on how it is computed. The SNs are often computed by using information explicitly given by the actors (e.g. most SNS) about its relations with other actors. Commonly, these relations are of trust, knowledge, or friendship, among others.

The SN can also be computed in an implicit way, through the observation of the actors' behavior and interactions. It is possible to gather a set of factors that allow to determine the existence (and intensity) of a relation between two actors. The most common are:

- Homophily which is the tendency to relate to similar individual (i.e. the assumption that two actors with similar profiles tend to have similar interests and a higher degree of proximity) [Luz, 2010];
- The assumption that two actors that have a similar relation with a determined element (e.g. when both like or dislike the same thing) have a higher degree of proximity [Luz, 2010];
- The tendency to relate to those related to someone known [Luz, 2010];
- The assumption that the more two actors interact with each other, the more their level of proximity increases (in interactions with positive outcomes) or decreases (in interactions with negative outcomes) [Yu and Wang, 2010];

[3] http://www.facebook.com/
[4] http://www.linkedin.com/
[5] http://www.hi5.com/

Each of these factors (or assumptions), or a combination of multiple ones, is often used to compute the SN. The meaning of the relations represented on the SN depends on the assumptions and techniques considered for their computation. Normally these relations allow inferring a degree of proximity between the actors that may indicate the likeliness of them having similar interests or behavior, or the likeliness of trusting each other.

2.6.2 Social Network Analysis

The analysis of social networks allows discovering relevant information about useful relations between entities, which is used to infer a trust level between them and predict the satisfaction of the client with a recommendation.

Social Network Analysis (SNA) is a research method centered in relations between subjects (normally individuals, organizations, among others) [Wasserman and Faust, 1994] [Scott, 1991] [Hannerman and Riddle, 2005]. However, it has also been applied in the analysis of relations between objects (such as documents, organisms, and molecules) [Zhou, 2009].

SNs are normally modeled using graphs or adjacency matrixes [Luz, 2010] [Yeh and Wu, 2010]. The graph theory allows not only the representation of the SN's structure, but also provides concepts and ideas to quantify and measure SN's properties [Luz, 2010] [Wasserman and Faust, 1994]. Some of the most commonly used concepts and properties of graph theory are:

- Directed (digraph) or undirected graph – indicates whether the vertices of the graph are directed, or not (bidirectional);
- Weighted or non-weighted graph – indicates whether the vertices of the graph have an assigned value, or not;
- Signed or unsigned graphs – indicates whether the vertices of the graph have an assigned sign, or not;
- Node degree – number of vertices connected to the node;
- Indegree – number of vertices directed to the node;
- Outdegree – number of vertices directed from the node;
- Length of a path – number of vertices on a path between two nodes;
- Weight of a path or distance in weighted graphs – sum of the weight of all the vertices from a path between two nodes;
- Geodesic – shortest path between two nodes;
- Graph density – in graphs with high density the number of vertices is close to the maximum allowed, whereas the low density graphs, also known as sparse graphs, have a reduced number of vertices;
- Cycle – a path with at least three nodes where all the vertices are distinct, except the firs and the last, which are the same;
- Semicycle – a digraph cycle where only the existence of a connection between the nodes is considered, independently its direction;
- Clique – an undirected graph, or subgraph, with maximum density;

- Graph diameter – the longest path between any two nodes;
- Graph average distance – average distance of the shortest path (geodesic) between any two nodes;
- Dyads and triads – sets of two or three nodes respectively and the possible connections between them.

SNA measures can support in the extraction of important information from the network. The majority of these measures focuses on a determined actor, or group, and may be used with various purposes, among them [Luz, 2010]:

- To identify prominent nodes, i.e., to identify nodes with high degree of notoriety. Some of the measures that can be used are centrality, closeness, betweenness, information and rank (or status), among others;
- To evaluate the community quality, using, for example, modularity and compactness measures;
- To perform positional analysis, i.e., to analyze the social position and role of an actor in the SN, and evaluate how two actors are structurally similar;
- To identify or exploit the nature of social relationships, through balance, clusterability and transitivity. For example, the balance theory allows studying how two actors react in a similar way to the same actor or object.

Prominence measures are also known as centrality and prestige measures. While the centrality measures focus on both the indegree and outdegree, the prestige measures focus only in the indegree. The simplest approaches for centrality and prestige focus on the degree of the node, i.e., the greater the degree (or indegree) of the node, the greater it is its centrality or prestige degree. The main prominence measures are:

- Degree centrality – measures the degree of centrality of a node and is directly related to the node's degree;
- Closeness centrality – measures the proximity of a node to all other;
- Betweenness centrality – measures the influence of a node or vertex in the flow of information through the network ;
- Degree prestige – measures the prestige degree of a node and it's directly related to the node's indegree.

2.6.3 Trust-based Recommendations

Trust (or confidence) can significantly improve the utility of a recommendation system [Zhou, 2009]. This statement is defended by some authors [Yu and Wang, 2010] [Yeh and Wu, 2010] [Zhou, 2009] that proposed different models for trust based recommendation systems, some of these incorporating SNA techniques. The obtained results by these authors show that the use of trust relations in recommendation systems allows overcoming some limitations and achieve better results than when using traditional recommendation models, such as the content based recommendation systems, collaborative recommendation system, among others.

Literature in trust based recommendation includes several works capable of isolate malicious agents when they behave in an expected way [Xiong and Li, 2004] [Zhang et al., 2009] [Hu et al., 2008] [Wen et al., 2009] [Li et al., 2008] [Wang and Wang, 2008].

For example, PeerTrust [Xiong and Li, 2004] determines the reliability of an agent taking into account the feedback given by other agents as well as their credibility. In [Wen et al., 2009] a model is proposed where the direct trust and indirect trust are considered. In this model the indirect trust is obtained through the transitive law of trust. The model presented in [Wang and Wang, 2008] combines a local trust measure with recommendation provided by other agents. The local trust is obtained through the direct experience of the agent considering the average of successful transactions with the other agent.

In [Das et al., 2011] a model is presented capable of dealing with malicious agents that adopt a highly dynamic behavior and act on an unpredictable way.

Based on the referred studies it is possible to gather a set of aspects that should be taken into account when designing a model to compute trust between two actors. These aspects are:

- Satisfaction – the level of satisfaction of all transactions between a pair of agents;
- Direct/Local trust – the trust from one agent to another, determined by the direct experience of the agent;
- Indirect trust – the trust from one agent to another, calculated by the experience of other agents in the system, particularly important when the agent has no direct experience with the other agent;
- Global trust – the trust from one agent to another, calculated by the weighted combination of direct trust and indirect trust, represents the expected behavior;
- Feedback credibility – when the system uses information provided by other agents it is necessary to take into account its credibility;
- Time decay of the trust values – the calculated trust values decay over time.

2.6.4 Trust-based Recommendations System Enhanced with SNA

In [Zhou, 2009] a trust based recommendation system prototype that includes SNA is presented. The system starts extracting connections and trust between users using SNA techniques, in order to build the users' trust network. The recommendations of products are made taking into account the built network. When the system has to decide whether or not to recommend a product or service, it takes into account the evaluation made by other users related to the user subject to the recommendation, and the trust value associated to each of the relations.

In [Yeh and Wu, 2010] a hybrid recommendation model is proposed which combines the collaborative and content based approaches with the latent topic discovery and SNA, in order to achieve the best prediction results. The results of the experiments show the advantage of combining these recommendation approaches as well as SNA.

In [Yu and Wang, 2010] a combined trust model is developed which, by considering the social network's topology and the frequency of interaction between users, is capable of inferring indirect trust relations.

2.7 Final Remarks

The literature in negotiation agents gives an important support to develop and implement AMEC systems [Lomuscio et al., 2001] [Jennings et al., 2001] [Sandholm and Vulkan, 1999] [Krovi et al., 1999]. However, usually each agent has its private ontology to describe their universe of discourse, their needs/capabilities. This raises a heterogeneity problem that is seen as a corner stone for agents' interoperability.

In general, current approaches consider simplified and limited solutions to deal with semantic problems. In this work the exploitation of the ontology matching paradigm is proposed as a solution for this problem, even though some works suggest that the resulting alignment may not be satisfactory to both agents and can become object of further negotiation between them [Mei et al., 2009].

One the other hand, the observation of the market activity, and the detection of emergent relationships between the market players, can lead to the establishment of more accurate trust relations between the participants as well as the improvement of the negotiations efficiency, both business negotiations and ontology alignment negotiations.

3 AEMOS the Proposed Model

3.1 Introduction

AEMOS (Agent-based Electronic Market with Ontology Services) [Silva et al., 2009] [Viamonte et al., 2011] [Viamonte et al., 2012] [Nascimento et al., 2012] is an agent-based electronic market platform that provides ontology services, more specifically, ontology matching services in order to facilitate the interoperability between agents that use different ontologies to represent the same domain of knowledge.

In this system, agents representing consumer or supplier entities negotiate with each other in order to reach deals, perform business transactions and satisfy the business goals of the entities they represent.

The main goal of this system is to enable an efficient and transparent negotiation between the agents even when they use different ontologies, ensuring that the agents are able to understand each other and correctly assess the terms and conditions of each transaction.

For that, the system follows an ontology-based information integration approach, exploiting the ontology matching paradigm [Euzenat and Shvaiko, 2007], selecting and suggesting possible alignments between the agents' ontologies and letting the agents choose which one should be used to translate the subsequent exchanged messages.

However, this approach raises new issues related to how the chosen ontology alignment may influence the business negotiation efficiency.

Ontology matching is a naturally ambiguous and subjective process, leading to different alignments that may be more or less adequate to each negotiation and therefore influence its efficiency and result. The quality and adequacy of an ontology alignment is very important in the negotiation, since it may determine the efficiency of the interaction. For example, a consumer may request a product that a supplier has on its inventory, but by using an inadequate alignment, relevant information may be lost during the transformation process causing the supplier not to be able to match it.

However, detecting incorrect or inadequate ontology alignments is not an easy task. The negotiation may fail because the alignment is inadequate to the current context, or they can also fail simply because the supplier doesn't have the desired products, or even because the agents have different goals (e.g. conflicting prices).

Moreover, the agents representing consumers and suppliers have the final decision about which alignment should be used in the negotiation, so they can apply their own preferences. However, while the agents are well aware of their own ontologies, they are naturally not acquainted with the others agents' ontologies and with the ontology alignments in such ill-specified ever-evolving environment.

In order to overcome these issues, the relevance of SNA in recommending ontology alignments for e-commerce negotiations is claimed, by including in the system a SN-based support component which, by capturing the agents' emergent SN and combining it with information collected during previous negotiations, is capable of improving the ontology alignments recommendations and supporting the agents' decisions about which alignment to choose.

3.2 General Overview

The AEMOS system is based on the ISEM system (cf. Section 2.4.1), which is an agent-based simulation system for e-commerce that aims to study agents' market strategies. In reality, the AEMOS system is an evolution of the ISEM system keeping all its original functionalities, but allowing agents' to use different ontologies to represent their domain of knowledge.

3.2.1 The Multi-Agent Model

Currently, the system includes several types of agents, as illustrated in Figure 5 (below), which compete and cooperate with each other in order to achieve their goals.

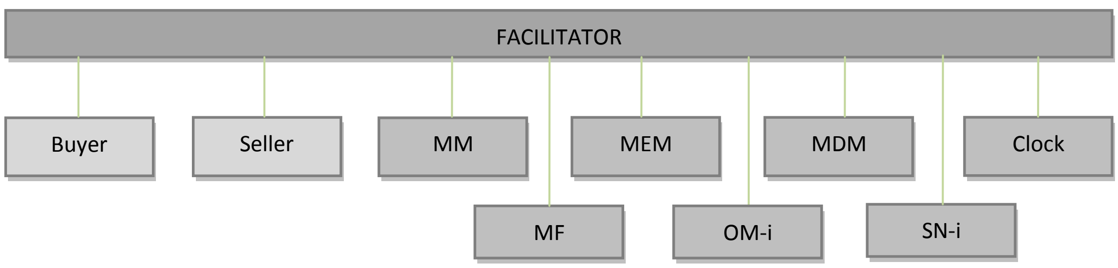

Figure 5 – AEMOS System Agents

The system recognizes 9 types of actors, classified in two main categories: the business (or external) agents and the supporting (or internal) agents.

The business agents represent real world entities whose behavior is intended to be simulated and studied. There are two types of agents in this category, namely:

- Buyer (B) – agent that represents a consumer, i.e., an entity, normally a person, wishing to acquire a set of products;
- Seller (S) – agent that represents a supplier, i.e., an entity, normally a company, wishing to sell a set of products.

The supporting agents are those who provide services that allow business agents to communicate with each other in order to perform business transactions, being responsible for the correct functioning of the market. This category includes the agents:

- Market Manager (MM) – agent responsible to manage all supporting agents and to register business agents so they can participate in the market. Normally there is only one agent of this kind per marketplace;
- Market Extension Manager (MEM) – agent that aids the MM agent on its functions, allowing the dynamic addition of machines where supporting agents may be initialized. The presence of this kind of agent is optional, although normally there are multiple agents of this type per marketplace;
- Market Data Manager (MDM) – agent that collects and maintains information about the market participants and their activities. Normally there is only one agent of this type per marketplace;
- Clock – agent that simulates the evolution of time notifying the appropriate agents about periodic (or scheduled) events. Normally there is only one agent of this type per marketplace;
- Market Facilitator (MF) – agent that coordinates the interaction between business agents, being responsible for ensuring that the communicating agents are able to understand each other. Normally there are multiple agents of this type per marketplace, being initialized by the MM agent when necessary. When a B agent is registered, an MF agent is associated such that, from that moment on, all messages related to the business negotiation process pass through the associated MF;
- Ontology Matching intermediary (OM-i) – agent responsible for the ontology matching services, recommending possible ontology alignments for each business negotiation, and transforming the exchanged messages according to the approved alignment. Normally there are multiple agents of this type per marketplace, being initialized by the MM agent when necessary. When an MF agent is initiated an OM-i agent is associated, such that, from that moment on, all the requests related to ontology matching services are sent to the associated OM-i agent;
- Social Network intermediary (SN-i) – agent responsible for the SN support, providing advice about the adequacy of the ontology alignments to each business negotiation. Normally there are multiple agents of this type per marketplace, being initialized by

the MM agent when necessary. When an OM-i agent is initiated, or a business agent registers in the market, a SN-i agent is associated; from that moment on all requests related to SN-based support are sent to the associated SN-i agent.

In addition to these types of agents there is the Facilitator, which is the agent responsible for establishing communications between the different agents of the system, matching agents' requests with registered agents' capabilities. This is the central component of any MAS based on the OAA platform which is the case of AEMOS.

Accordingly, the multi-agent model can be view as a system composed of three layers, as illustrated in Figure 6 (below), where the agents of the higher layers use features provided by the agents of the lower layers in order to execute their tasks.

Figure 6 – Layers of the AEMOS System

The MM, MEM, MDM and Clock agents are the group of supporting agents responsible for the system's management granting its dynamism, flexibility and correct functioning. Although necessary for the system to cope with the complexity of the proposed model, these are not the focus of this work and therefore they will not be detailed further. More information about these agents is presented in Annex A – System Management Agents.

On the other hand, the MF agent and the business agents will be presented in further detail in Sections 3.3 and 3.4 respectively.

The OM-i and SN-i agents, main component of the proposed model, and the main focus of this work, will be detailed in the Chapter 4, Sections 4.2 and 4.3 respectively.

3.2.2 The Interaction Protocol

To be able to communicate with each other the agents need common norms, including a communication platform and language. Since AEMOS is based on ISEM, the OAA platform was selected as the communication platform and, consequently, the ICL language as the communication language (cf. Section 2.3.3).

To participate in the market, the business agents must first register, providing their identification and indicating the list of ontologies that they use. Optionally, the agents may also share (parts of) the profile of the entity they represent. The registry is handled by the

MM agent that ensures that the appropriate agents store the information, namely the MDM agent, MF agents, and SN-i agents.

When the registration of B agents occurs, the MM agent also associates a MF agent for which the B agent should send all the requests related to business negotiations.

Once registered, the agents are allowed to negotiate. For that the B agents start announcing their buying products and wait for S agents to formulate proposals. Figure 7 (below) illustrates the interaction between agents during a business transaction negotiation.

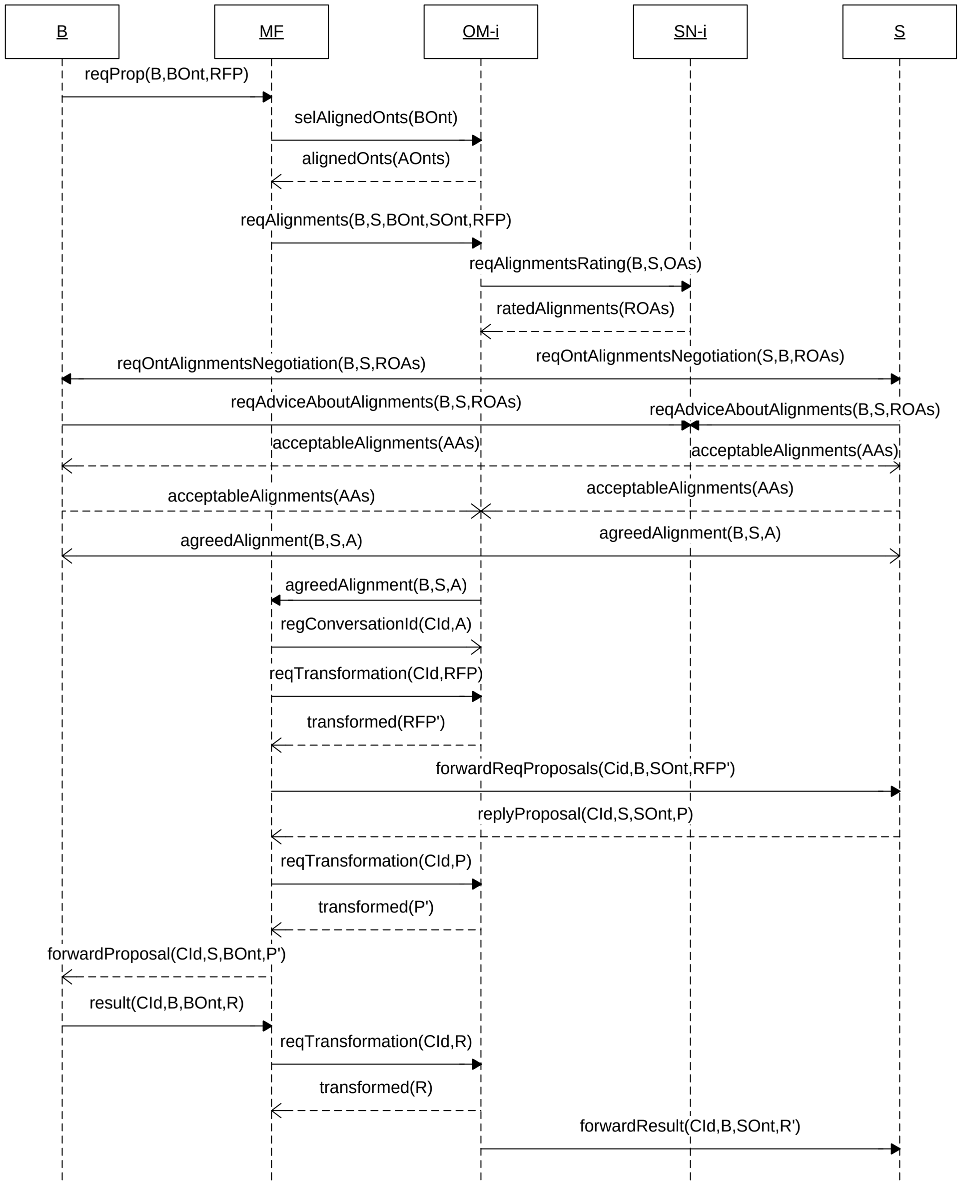

Figure 7 – Interaction between Agents during a Business Negotiation

When the negotiation starts, the MF agent must select the S agents that might be able to satisfy the B agent's request. Here, an ontology-based approach is followed, such that the MF agent selects both:

- The S agents that use the same ontology as the B; and,
- Supported by the OM-i, the ones that use ontologies that can be aligned with it.

Therefore, the business negotiations may occur in two different scenarios:

- Both agents use the same ontology – the MF agent acts as a proxy between B and S, simply receiving and forwarding messages;
- The agents use different ontologies (scenario represented in Figure 7, above) – it is necessary to find an agreement about the alignment between the respective ontologies that should be used to translate the exchanged messages. For that the MF agent requests the OM-i agent to mediate an ontology alignment negotiation between B and S agents. If an agreement is achieved, the subsequent exchanged messages are sent to the OM-i agent, which translates their content according to the agreed alignment ensuring that the message receiver will be able to understand it.

During the business negotiation the involved agents, B and S, exchange proposals and counterproposals, terminating the negotiation when an agreement is achieved or when they have no more proposals to formulate.

When a business agent satisfies all its business goals, or their deadlines are reached, it must terminate its activity notifying the market and declaring the achieved results. This un-registration process is handled by the MM and MF agents, and the given information is stored by the MDM agent.

As described above, during the market activity two types of negotiations may occur, namely (i) business negotiations, and (ii) ontology alignment negotiations.

In AEMOS the ISEM's business negotiation protocol (cf. Section 2.4.1.2) remains unaltered and therefore will not be addressed further. On the other hand, the ontology alignments negotiation is a new feature.

3.2.3 Ontology Alignment Negotiation

The ontology alignment negotiation initiates when an MF agent sends a request to the OM-i agent identifying (i) both agents, (ii) the respective ontologies and (iii) providing information about the request originally made by the B agent.

The ontology alignment negotiation follows an approach similar to the one used for business negotiations. Figure 8 (below) presents the exchanged messages during this kind of negotiation.

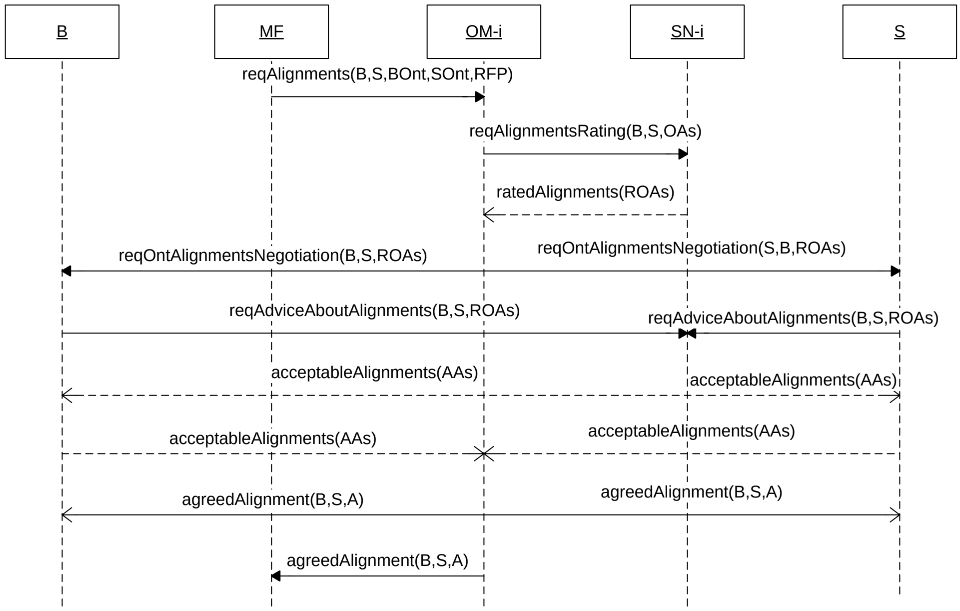

Figure 8 – Ontology Alignment Negotiation Protocol

The OM-i agent selects, from its repository, all the possible alignments between the indicated ontologies. Then performs sorting and filtering actions following its internal criteria and/or requesting a SN-i agent to rank the alignments taking into account the information about the agents and the request made by the B agent (scenario illustrated in Figure 8, above), constructing a set of possible alignments and their respective score, which will be sent to both B and S agents in an ontology alignment negotiation request.

Each business agent, B and S, analyze the recommended alignments taking into account their preferences and/or requesting advice of a SN-i agent, replying to the OM-i agent the list of alignments that they consider acceptable.

The OM-i agent analyzes both replies and checks if there is an agreement, i.e., if some alignment was selected by both agents. If there is no agreement, depending on the system configuration, the negotiation may terminate, or proceed, with the OM-i agent refining its list of recommended alignments and asking agents to reconsider their options and criteria.

If there is an agreement, the OM-i agent notifies both agents and the MF agent about the agreement and proceeds with the transformation of the request made by the B agent. From that moment on, all the subsequent exchanged messages between the agents are forward to the OM-i agent for transformation.

3.3 The Market Facilitator Agent

The Market Facilitator (MF) agent is responsible for the information integration process in the messages exchanged between business agents. It is an intermediate agent during the negotiation process that ensures that both parties are able to understand each other (i.e. use the same semantics).

This agent is responsible for the establishment and coordination of conversations between agents, being capable of selecting S agents that might be able to satisfy a request made by a B agent (cf. Section 3.3.1), and then coordinating the established conversations (cf. Section 3.3.2).

3.3.1 Selecting Appropriate Sellers for a Buyer's Request For Proposals

A negotiation starts when a B agent sends a request for proposals (RFP), as described in the interaction protocol section (cf. Section 3.2.2). Then the request is sent to a MF agent so it can select the appropriate S agents.

Here an ontology-centered solution is proposed where the MF agent selects the S agents that use the same ontology as the B agent and, supported by the OM-i agent, selects the ones that use ontologies that can be aligned with it.

For that the MF agents starts by requesting OM-i information about ontologies that can be aligned with the one used by the B agent to describe the requested product. In return the OM-i agent sends the list of ontologies, if there is some.

The MF agent then checks its registered S agents' record and selects the ones that use the ontology used by the B agent or some of the ones returned by the OM-i agent.

For each of the selected S agents the MF agent will then verify if a conversation can be established and, if so, will coordinate it.

3.3.2 Coordinating Agents' Conversations

In order to establish a conversation between two agents either the agents use the same ontologies or they must reach a consensus about the ontology alignment to adopt between their respective ontologies.

Once these conditions are met, the MF agent coordinates the conversation between the agents, ensuring that each exchanged message is described according to the conceptualization used by its receiver. For that, when a conversation occurs between agents that use different ontologies, each exchanged message is sent to the OM-i agent for transformation according to the previously agreed alignment.

In AEMOS the conversations between agents, i.e. the set of exchanged messages during a negotiation, are uniquely identified. In case of business negotiations, this identification is attributed by the MF agent.

By identifying the conversation, the MF agent is able to register information about the alignments that are used (if any), so when a new message arrives in the scope of a business negotiation, the MF agent knows instantly if it should send it to the OM-i agent for transformation, or forward it directly to its addressee.

3.4 The Business Agents

The business agents represent the users of the AMEC system, wishing to transact products. The market activity and evolution will be directly affected by the business agents' behavior. These agents are highly customizable, adaptable and dynamic.

3.4.1 The Buyer Agent

A Buyer (B) agent represents a consumer in the market, i.e., an entity, normally a person, desiring to acquire a set of products.

B agents are highly customizable. For that a large amount of initial parameters is provided and defined by the user. The configuration of a B agent can be divided in three main parts:

- Profile – personal data and general preferences of the entity to represent;
- Strategic behavior – behavior definition;
- Shopping List – set of orders to satisfy (i.e. consumer's needs) with their respective preferences and restrictions.

The information about the represented entity's profile is very important to perform market studies (e.g. Market Knowledge Agent in ISEM, cf. Section 2.4.1) and to support the SN-based component (cf. Section 4.3.3.1).

A B agent's profile includes information about the represented entity's gender, location, profession, favorite brands, etc. An example of a B agent's profile is given in Figure 9.

Figure 9 – A Buyer Agent's profile

In the configuration of a B agent's strategic behavior a set of parameters, including the agent's market strategies studied in ISEM, are defined in order to control and restrict the agent's behavior. Table 1 represents the behavior parameters that are relevant in the scope of this thesis.

Table 1 – Relevant Behavior Parameters of a Buyer Agent

Parameter	Description
Exigency Level	A number varying between 0 and 1 which represents the level of exigency of the agent. The closer the number is to 1 the higher is the agent's exigency.
Trust Level	A number varying between 0 and 1 which represents the level of trust of the agent with the system. The closer the number is to 1 the higher is the agent's trust on the system.
Minimum Score	A number that indicates the minimum score to consider acceptable an ontology alignment.
Minimum Number of Negotiations For Score Credibility	Indicates the minimum number of business negotiations where the ontology alignment was used to consider credible an ontology alignment adequacy evaluation.
Score Credibility Percent	The percent that it should fade (or increase) on the given score if the number of negotiations where the alignment was used is lower than its minimum defined.

The B agent's Shopping List represents its business goals. The agent is initialized with a set of orders to satisfy being specified for each one, (i) the product's characteristics and (ii) its respective relevance, (iii) the quantity to acquire, (iv) its price restrictions and (v) its deadline. Figure 10 illustrates a set of orders from a B agent's shopping list.

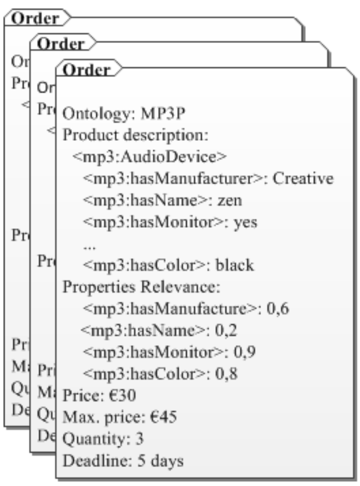

Figure 10 – A Set of Orders from a Buyer Agent' Shopping List

As illustrated in Figure 10 (above), a consumer may indicate the preferential characteristics for the product (*Product Description*) and then indicate the relevance it attributes to each property (*Properties Relevance*). In the example given in Figure 10, the desired product is an audio device named “Zen” manufactured by “Creative” in black color and with a monitor. However the consumer indicates that while the color and existence of monitor are very important, the other characteristics have a lower relevance.

The consumer indicates the ideal characteristics, and gives the agent some autonomy to search for similar products.

3.4.2 The Seller Agent

A Seller (S) agent represents a supplier in the market, i.e., an entity, normally a company, desiring to sell products. Its main goal is to sell a list of products following the preferences and restrictions of the entity it represents.

Like B agents, the S agents are highly customizable possessing a large amount of initial parameters. The configuration of a S agent can also be divided in three main parts, namely:

- Profile – information and general preferences of the entity to represent;
- Strategic behavior – behavior definition;
- Inventory – set of products to sell (i.e. supplier’s capabilities) with their respective preferences and restrictions.

The information about a supplier’s profile serves a similar purpose as the consumer’s profile. However, since it refers to a company rather than an individual, a S agent’s profile includes different information. An example of a S agent’s profile is given in Figure 11.

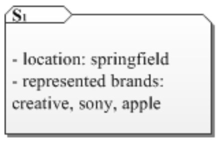

Figure 11 – A Seller Agent’s Profile

In the configuration of the S agent’s strategic behavior a set of parameters, including the agent’s market strategies studied in ISEM, are defined in order to control and restrict the agent’s behavior. S agents’ behavior parameters are different from the ones used in B agents. However the ones relevant in the scope of this thesis are similar to the ones described for B agents in Table 1 (cf. Section 3.4.1).

The business goals of the S agent are represented by its Inventory. The agent is initialized with a set of offers, being specified for each one (i) the product’s characteristics, (ii) the quantity in stock, (iii) its price restrictions and (iv) its deadline. Figure 12 (below) illustrates a set of offers from a S agent’s inventory.

Figure 12 – A Set of Offers from a Seller Agent’s Inventory

3.4.3 Stages of a Business Agent’s Behavior

B and S agents initiate their activity following the stages of a business agent’s behavior, as illustrated in Figure 13.

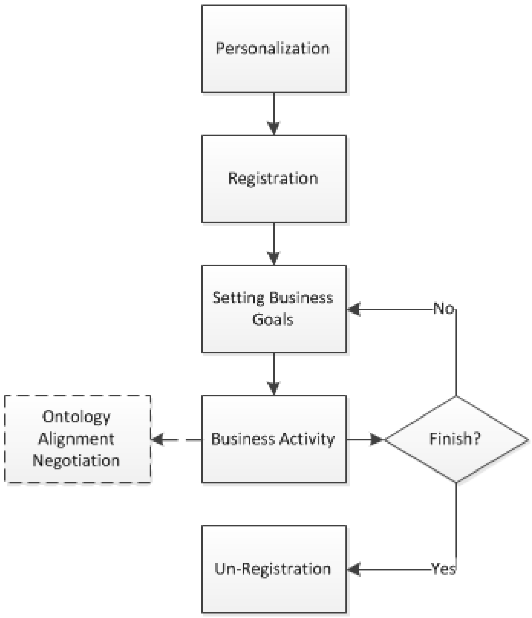

Figure 13 – The Stages of a Business Agent’s Behavior

The business agents initiate their activity by personalizing themselves according to the information transmitted on their configuration, defining the business strategies to be followed, and initializing the parameters of their utility functions, which includes determining the relevance (weight) that each entity of the used ontologies should have in their decisions (cf. Section 3.4.4).

The agents then register on the market, set their initial business goals following the defined strategies and initiate their business activity.

The business activity is different for B and S agents. While the B agents announce the products that they wish to acquire and wait for S agents to formulate proposals, the S agents analyze the announcements made by B agents, check their capabilities and current availability and try to formulate proposals for the announced products.

Both agents then proceed with the transaction negotiation following the defined negotiation protocol, and updating their business goals following the outcomes of the negotiations.

During the business activity, the agents may need to negotiate the ontology alignment in order to be able to negotiate with agents that use different ontologies. Here the agents may request advice from a SN-i agent (Section 3.4.6.2) in order to select the alignments that best meet their preferences.

When the agents satisfy their business goals, or reach the specified deadlines, they terminate their activity notifying the system that they are leaving and declaring the results that they achieved (e.g. a B agent may indicate (i) the number of satisfied orders, (ii) the total number of orders that it was supposed to buy and (iii) total amount spent; and a S agent may indicate (i) the number of sold units, (ii) the total number of units that it was supposed to sell and (iv) the total profit).

3.4.4 Ontology's Entities' Relevance to the Agent

During the personalization process, the business agents analyze their shopping lists or inventories, and determine the relevance (weight) that each property or concept (i.e. entity), of the used ontologies should have on their decisions.

In this model a simple approach is followed to determine this relevance based on the frequency of the use of each ontology entity in relation to the other entities of the same ontology.

In case of a B agent, the information about the properties' relevance in each order of its shopping list is also analyzed, determining the average relevance value attributed to each ontology's entity.

The agent determines the relevance of each ontology's entity following a process composed of four steps:

1. The agent counts the occurrences of each ontology's entity;
2. The agent calculates the frequency of each entity in relation to the other entities from the same ontology; If the agent is a S agent, then it stops the process here; otherwise,
3. The agent determines the average relevance value attributed to each entity;
4. The final relevance will obtained by averaging the values from steps 2 and 3.

For example, consider the orders presented in Figure 14 (below) as a B agent's shopping list.

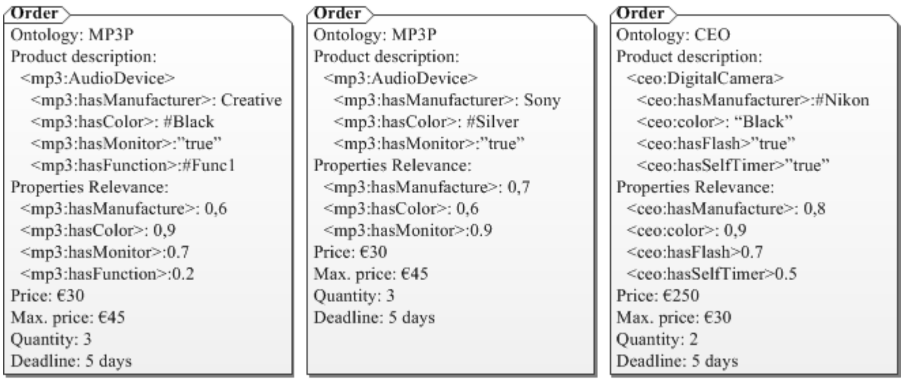

Figure 14 – A Buyer Agent's Shopping List

The values obtained in the followed steps are illustrated in Table 2.

Table 2 – Determining the Relevance Value of Each Ontology Entity

Ontology	Entity	1. Count	2. Frequency	3. Average Relevance	4. Relevance Value
MP3P	hasManufacturer	2	0.286 (2/7)	0.65	0.468
	hasColor	2	0.286 (2/7)	0.75	0.518
	hasMonitor	2	0.286 (2/7)	0.8	0.543
	hasFunction	1	0.143 (1/7)	0.2	0.172
CEO	hasManufacturer	1	0.25 (1/4)	0.8	0.525
	Color	1	0.25 (1/4)	0.9	0.575
	hasFlash	1	0.25 (1/4)	0.7	0.475
	hasSelfTimer	1	0.25 (1/4)	0.5	0.375

These relevance values will then be used to evaluate the recommended ontology alignments (cf. Section 3.4.6.3).

3.4.5 Evaluating Products by their Descriptions

During a business negotiation, a critical factor in formulating or analyzing proposals, as well as determining the satisfaction of a B agent with a purchased product, is the similarity between the requested/desired product and the proposed/purchased product.

Since each product is described according to an ontology, this similarity will be determined by comparing the attributes of two instances of the same ontology; one that describes the requested/desired product and other which represents the proposed/purchased product.

In order to perform this comparison, various similarity measures are used, depending on the type of value to analyze, e.g. the "levenshtein distance"[6] can be used to determine the

[6] http://en.wikipedia.org/wiki/Levenshtein_distance

similarity between two string values. These measures can be found in software packages such as SimPack[7].

As mentioned in section 3.4.1 (The Buyer Agent), and illustrated in Figure 10 (– A Set of Orders from a Buyer Agent' Shopping List), B agents can also define a specific relevance (weight) for each ontology's entity used to describe a product of an order. This relevance should be considered when evaluating product proposals.

For example, considering the scenario presented in Figure 15 (below), where the B agent analyzes two proposals (*PP1* and *PP2*) for the desired product.

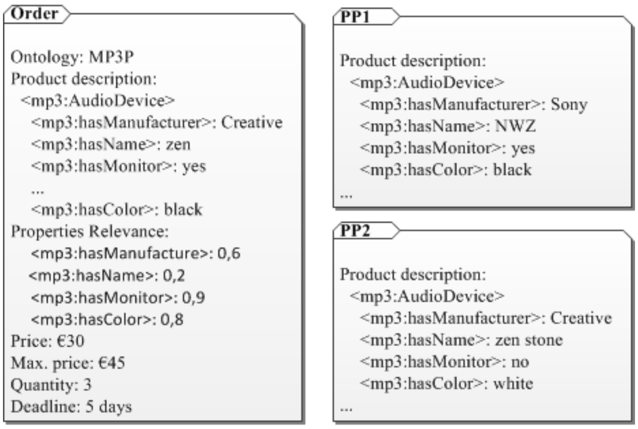

Figure 15 – An Example of a Buyer Agent's Order and Proposals to Analyze

For each proposal, the agent will calculate its utility ($ppUtil$) taking into account the similarity of each attribute weighted by its relevance. A formalization of the process is given by:

$$ppUtil(d_{pr}, d_{pp}, r_{pr}) = \sum \left(r_{pr_i} . simF_i\left(d_{pr_i}, d_{pp_i}\right)\right) / \sum r_{pr_i} \quad (1)$$

Where d_{pr} is the description of the desired product, d_{pp} is the description of the proposed product, r_{pr} is the information about the desired product's properties' relevance; r_{pr_i} is the relevance of the property (pr_i) being compared, d_{pr_i} and d_{pp_i} are the values of the attribute being compared in the required product (pr_i) and in the proposed product (pp_i) respectively, and $simF_i$ is the method used to determine the similarity between the values.

For the example given in Figure 15 (above), considering simple matching measures (where $simF_i$ returns 0 when the values are different or 1 when they are equal), the agent will obtain a utility value of 0.68 for the proposal *PP1* and one of 0.32 for the proposal *PP2*. Hence, despite having the same amount of similar characteristics, the *PP1* provides the ones the B agent values most.

[7] https://files.ifi.uzh.ch/ddis/oldweb/ddis/research/simpack/index.html

3.4.6 Evaluating the Ontology Alignments

Given the versatility of the system and its agents, there are three methods for the business agents to select the acceptable ontology alignments, namely:

- By considering only the evaluation performed by the OM-i agent;
- By requesting advice from a SN-i agent;
- By analyzing the alignment taking into account the relevance given to each entity of the involved ontology.

The selection of the method to apply is related, essentially, with the agent's level of exigency and/or trust in the system, transmitted during its configuration.

Each of these methods will be addressed in the following subsections.

3.4.6.1 By Considering OM-i Agent's Evaluation Only

When using this method, the agents simply sort the alignments by the score attributed by the OM-i agent, and possibly applying a minimum score for filtering.

This method is normally used when the agent has a low level of exigency and/or a high level of trust on the system. Its use is also advised when there is only one SN-i agent in the system which ranks the alignments for the OM-i agent.

3.4.6.2 By Requesting Advice from a SN-i Agent

Using this method the agent requests a SN-i agent to evaluate each recommended alignment to determine its adequacy to the agent and to the actual negotiation.

The SN-i agent then returns (i) the score resultant from the alignment evaluation and (ii) information allowing the agent to deduce and decide about the confidence it should attribute to the evaluation performed by the SN-i agent.

This second type information is very important since the evaluation performed by the SN-i agent will be affected by the previous usage of the alignment. For example, the evaluation of an alignment that has been used in a reduced number of business negotiations should have a low level of accuracy. The agents should then decide about the alignment's acceptance taking into account these two factors.

In order to be able to compare alignments that were used in a different number of negotiations, a simple approach is followed where the agent assumes that when the number of previous negotiations is reduced two scenarios may occur: (i) the alignment's score is incorrectly low and should be raised, or (ii) the alignment's score is improperly high and should be lowered.

The general method followed by business agents to evaluate the score attributed by the SN-i agent to an ontology alignment is presented in the following code snippet (Code 1).

```
scoreInc = 0;
if (numNegs < minNumNegs)
       scoreInc = credibilityPer * sniScore;
       if(sniScore >= minScore)
              scoreInc = -scoreInc;
acceptanceLevel = score + scoreInc;
```

Code 1 – General Method to Evaluate an Ontology Alignment's Score

Where *acceptanceLevel* is the alignment's acceptance level for the agent, *sniScore* is the score attributed by the SN-i agent to the alignment, *numNegs* is the number of previous business negotiations where the alignment was used, and *minScore, minNumNegs* and *credibilityPer* are the minimum score, minimum number of negotiations for score credibility and score credibility percent that were presented in Table 1 (cf. Section 3.4.1).

This is the most frequently used method, usually used by agents with a medium level of both exigency and trust in the system.

3.4.6.3 By Analyzing the Ontology Alignment

In this last method, the agents analyze the alignments taking into account the relevance they attribute to each entity of the ontology in question. This method is normally used only when there is no SN-i agent on the system, although it can also be used when the agent has a high level of exigency and/or a low level of trust in the system, or when it intends to deploy a more selfish behavior disregarding the preferences of its negotiation partner.

A formalization of this method is given by:

$$alignmentUtil(cp, ncp, rp) = \frac{\sum rp(cp_i) - \sum rp(ncp_i)}{\sum rp_i} \tag{2}$$

Where *cp* is the set of properties and concepts both relevant to the agent and covered in the alignment, *ncp* is the set of properties and concepts which are relevant to the agent but not covered in the alignment and *rp* is the information about the relevance attributed to each property or concept by the agent.

3.5 Final Remarks

This chapter presented the proposed model for the AEMOS system, which is an agent-based electronic market platform that provides ontology matching services improved by the application and exploitation of the trust relationships captured by the social networks.

The system enables an efficient and transparent negotiation between the agents even when they use different ontologies, ensuring that they are able to understand each other and correctly assess the terms and conditions of each transaction.

4 Ontology Services and Social Network Support

4.1 Introduction

Given the natural ambiguity of the ontology matching process, raising the possibility of multiple alignments between the same pair of ontologies, it is necessary to choose the one that best meets the interests of both agents. However, since the agents may possess different interests, the ontology alignment may also become object of further negotiation.

In this context, the application and exploitation of relationships captured by social networks can result in the establishment of more accurate adequacy relations of ontology alignments to agents, as well as the improvement of the negotiations efficiency and therefore the users' satisfaction with the electronic commerce system.

This chapter presents details about the AEMOS ontology services and the social network component.

4.2 The Ontology Services

When two agents that use different ontologies (to represent the same domain of knowledge) wish to exchange messages, a set of intermediary processes are necessary. These processes correspond to:

- Discovering the correspondences between both ontologies – ontology matching process;
- Represent the discovered correspondences so they can be applied in data transformation – ontology alignment document;
- Transform the content of the message according to the ontology alignment – ontology's instances transformation process;

In AEMOS the ontology services are provided by the Ontology Matching intermediary (OM-i) agent. The OM-i agent is responsible for the ontology alignments' management and for the ontology instances transformation process, being able to propose ontology alignments, coordinate ontology alignment negotiations, and transform ontology's instances when requested. Its main components are illustrated in Figure 16.

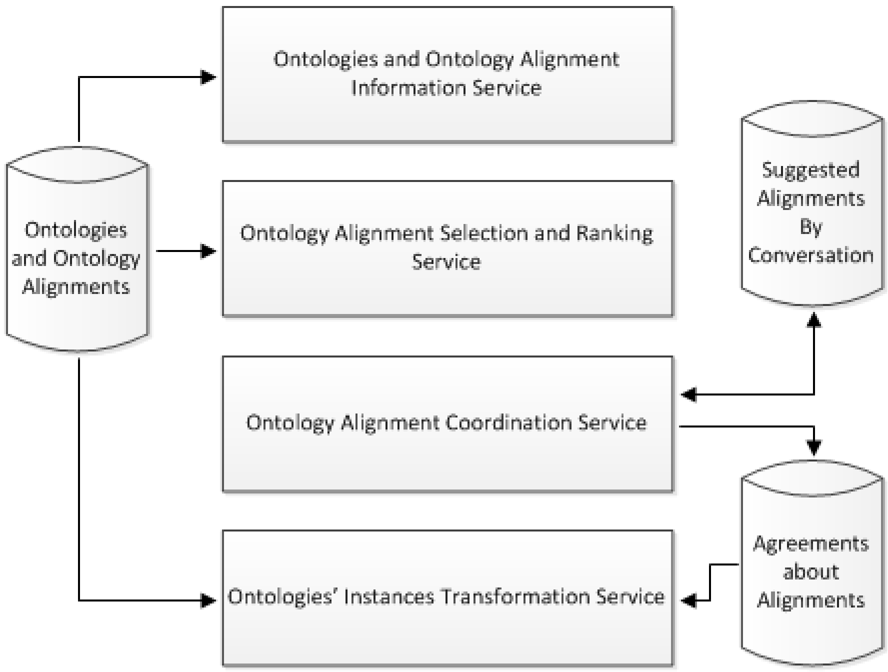

Figure 16 – The Main Components of an OM-i Agent

The OM-i agent collects information about ontologies and ontology alignments. During its activity the OM-i agent stores and maintains information about achieved ontology alignments' agreements and recommended alignments during each ontology alignment negotiation.

The agent is able to provide information about ontologies and ontology alignments, e.g. when it is requested by the MF during the S agents' selection process (cf. Section 3.3.1), and has three main responsibilities:

- Selecting and Ranking ontology alignments for a given business negotiation;
- Coordinating the ontology alignment negotiation process;
- Transforming data/message content, i.e. the ontology's instances.

Each of these responsibilities is described in the following subsections, presenting first some clarifications about the ontology alignments repository.

4.2.1 Ontology Alignments Repository

Currently, the ontology matching process is performed externally to the negotiation process. It is then considered a registry of the ontologies that are recognized and a repository of possible alignments between them (cf. *Ontology and Ontology Alignments*, in Figure 16, above). This information can be updated any time, as new ontologies and ontology alignments are added to the system.

It is assumed in AEMOS that agents represent their domain of knowledge using public ontologies, i.e., ontologies that are publicly accessible, having their own web page (e.g. the Consumer Electronics Ontology[8]) or being stored in web repositories, such as TONES[9], Falcons[10] or Swoogle[11]. Therefore it is possible to gather the ontologies that are used in an e-commerce context and discover possible alignments between them, or even collect already existent alignments from public web sources (e.g. NCBO BioPortal[12]).

The ontology matching process can be performed multiple times, possibly using different methods, giving rise to various possibilities of alignment between the same pair of ontologies.

4.2.2 Selecting and Ranking Ontology Alignments for Negotiation

The OM-i agent selects from its ontology alignments repository the ones that involve both ontologies of the negotiating agents. It then ranks the alignments using one of two methods (depending on the system's configuration):

- By analyzing the alignment taking into account information about the request made by the B agent and previous agreements related to each of the involved agents;
- By requesting a SN-i agent to rank the alignments accordingly to both agents and the information about the request made by the B agent.

Each of these methods is addressed in the following subsections.

4.2.2.1 By Analyzing the Ontology Alignment

Normally, this method is used only when there is no SN-i agent in the system. The OM-i agent sorts the alignments taking into account the ontology's entities used by the B agent to describe the requested product, i.e., the alignments that cover a higher amount of ontology's entities used by the B agent will have a higher evaluation value. A formalization of the process is given by:

$$alignmentUtilForNeg(alce, pdue) = \frac{|alce \cap pdue|}{|pdue|} \tag{3}$$

Where *alce* is the set of ontology's properties and concepts that are covered in the alignment and *pdue* is the set of ontology's properties and concepts used in the description of the requested product.

[8] http://www.ebusiness-unibw.org/ontologies/consumerelectronics/v1
[9] http://owl.cs.manchester.ac.uk/repository/
[10] http://ws.nju.edu.cn/falcons/ontologysearch/
[11] http://swoogle.umbc.edu/
[12] http://bioportal.bioontology.org/mappings

For each of the selected alignments the OM-i agent may reinforce its evaluation value depending on the existence of previous agreements involving the alignment and the agents.

4.2.2.2 By Requesting Advice from a SN-i Agent

This method is similar to the one used when a business agent requests advice from the SN-i agent about which alignments to choose (cf. Section 3.4.6.2). However, in this case, the OM-i agent is able to send information about the request made by the B agent.

The SN-i agent returns the same type of information as it does for business agents, i.e., for each alignment indicates the evaluation value and the number of previous business negotiation where it was used, and the OM-i agent follows the same evaluation method presented in Code 1 (cf. Section 3.4.6.2).

4.2.3 Coordinating Ontology Alignment Negotiation

This negotiation follows the protocol described in section 3.2.3 (Ontology Alignment Negotiation).

The OM-i agent starts by selecting and ranking the alignments that involve both ontologies as described in the previous topic. In fact, the OM-i selects two types of alignments, building and evaluating not one but two sets of alignments:

- One with the alignments from the B agent's ontology to the S agent's ontology; and
- Other with the alignments for the inverse direction.

Therefore, the ontology alignment negotiation process will succeed only if one alignment in each direction is accepted by both agents.

Like any negotiation in AEMOS, the ontology alignment negotiation is uniquely identified, so the OM-i agent is able to register the alignments recommended in each iteration in order to refine its future recommendations.

4.2.4 Ontology's Instance Transformation

The transformation of a message's content (ontology's instance) is performed using the ontology alignment agreed by the agents during the ontology alignment negotiation process, and that is stored in the ontology alignments repository.

The process is executed by using an information integration tool, such as the MAFRA Toolkit (cf. Section 2.5.3), and it is transparent to the agents. However, its details are also out of the scope of this thesis.

4.3 The Social Network Support

In AEMOS the SN-based support is provided by Social Network intermediary (SN-i) agents, which are responsible for the discovery of agents' proximity relations that emerge during their activities in the market.

The SN-i agents are introduced in the system in order to enhance the communication efficiency, supporting the OM-i agents at the ontology alignments recommendation and advising business agents about recommended ontology alignments.

As it can be seen from previous descriptions, these agents are able to perform these tasks without the SN-i agent's support; however there are some limitations that may affect the negotiation efficiency.

Without using the SN-i agent's support, the OM-i agents assume that the alignments are always semantically correct and equally adequate to any situation involving a pair of ontologies, as long as some of the ontology's entities used on the requested product's description are contemplated in the alignment. However, since the use of different techniques may lead to different alignments, this accuracy is not guaranteed.

Moreover, the OM-i agent can select and rank ontology alignments taking into account the ontology's entities used to describe the B agent's requested product, however it has no information about the relevance that B agent gives to each one (e.g. an alignment can contemplate more of the used entities but not the ones the B agent values most), and it doesn't consider the S agent's preferences either.

On the other hand, the B and S agents have the final decision about which alignments should be used in the business negotiation, so they can apply their preferences. However they may not possess knowledge that enables them to analyze and evaluate the alignments.

The SN-based component is introduced based on the assumption that taking into account captured emergent relationships between the agents and the overall usage of the ontology alignment, should result in a more accurate evaluation and usage of the ontology alignment, as well as a higher negotiation efficiency between negotiation partners.

For that, during the market activity, information about its participants and their interactions is collected and maintained. This information is then provided to the SN-i that applies SNA techniques in order to support the OM-i agent in recommending ontology alignments, and to support both B and S agents in deciding which alignments to choose. Figure 17 (below) illustrates the main components of a SN-i agent.

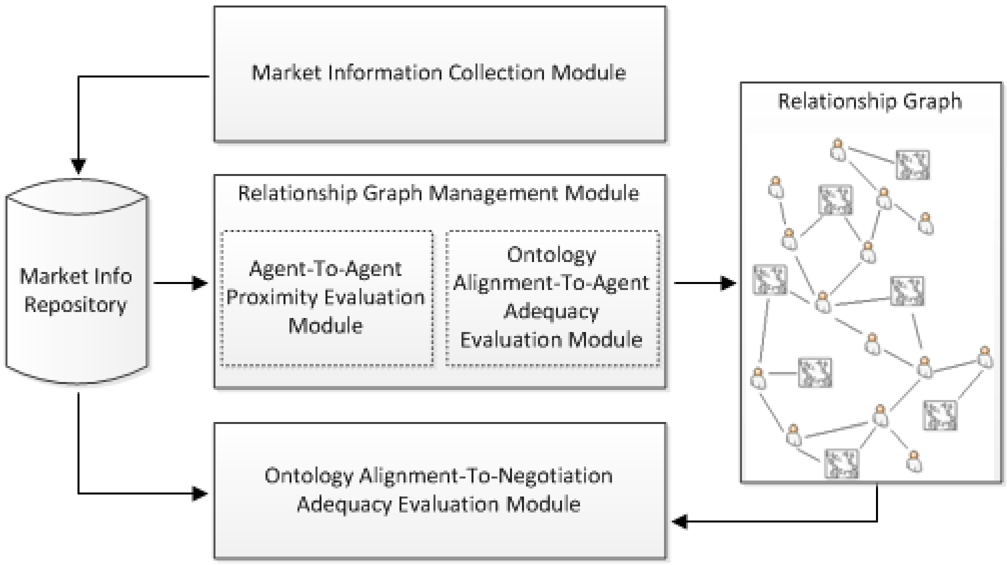

Figure 17 – The Main Components of a SN-i Agent

The SN-i agent has three main responsibilities, namely:

- Collect information about market participants and their activities, storing it in the *Market Info Repository*;
- Build and maintain the *Relationship Graph*, which includes:
    - Evaluating proximity relations between agents;
    - Evaluating ontology alignments adequacy to agents;
- Determine the adequacy of an ontology alignment to a business negotiation.

Each of these responsibilities will be addressed in the following subsections.

4.3.1 Collecting Information throughout the Market

The SN-i agent receives information from the other agents on the market that will allow it to, in return, support them in their tasks. This information is stored in the *Market Info Repository* which corresponds, in reality, to a set of repositories, as illustrated in Figure 18.

Figure 18 – The Components of a SN-i Agent's Market Info Repository

When a business agent registers in the market, the SN-i agent collects and stores the provided information, namely information about its profile and valued ontologies' entities.

As an intermediary in business negotiations, the MF agent has the ability to provide impartial information about the business negotiations between the business agents (e.g. both agents' identification, the used ontology alignments, indication if the B agent tried to close deal, the negotiation outcome, the satisfaction of B agent with the deal).

The OM-i agent is capable of providing information about known ontologies, existent ontology alignments and ontology alignment negotiations between the business agents.

As stated in [Das et al., 2011], a common problem of SNA models implementations, that register information about interactions, is the exponential growth of the information repositories, due to the large amount of information that needs to be stored. In order to overcome this issue, instead of recording all interactions, the SN-i agent stores the information, in an accumulative way (i.e. sums, counts and tendencies) grouped by agent, ontology alignment, pair of agents, and pair agent and ontology alignment.

This approach allows avoiding the exponential growth of the repositories, as well as enhancing the agent's performance.

4.3.2 Building and Maintaining the Relationship Graph

The SN is modeled using a relationship graph which includes two types of nodes, namely business agents and ontology alignments, and two types of relations, namely proximity relations between business agents and adequacy relations from ontology alignments to business agents.

A relation between two agents represents the level of proximity between them, i.e., the probability of the agents having similar interests and, therefore, reaching successful agreements. These relations have an associated value, ranging from -1 (inclusive) to 1 (inclusive), which represents the intensity of the relation and that is obtained following the method detailed in the following section (Section 4.3.3).

The relations between agents and ontology alignments are included in the SN to enhance performance, facilitating their rapid consultation and maintenance. This type of relations represents the adequacy of the ontology alignment to the agent having an associated value, also ranging from -1 (inclusive) to 1 (inclusive), that is obtained following the method described in a later section of this chapter (cf. Section 4.3.4).

The SN-i agent starts building the SN as the business agents register in the market. It then updates the computed SN periodically and whenever it receives new information from other agents in the market.

When the SN-i agent receives new information, it checks which agents and ontology alignments are involved in this new information, updating in the SN only the relationships concerning these elements.

As mentioned in the previous section, the SN-i agent may receive three kinds of information, performing the respective update tasks:

- When it receives information about the registration of a new business agent, the SN-i agent includes the new agent in the SN computing its relations with each one of the already existing agents, and ontology alignments;
- When it receives information about a business negotiation, the SN-i agent updates the relations between the involved agents and, if it's the case, updates the relations of the indicated ontology alignments to each of the involved agents;
- When it receives information about an ontology alignment negotiation, the SN-i agent updates the relations between the involved agents.

Periodically the SN-i agent revises the entire SN, updating the relations between the agents by analyzing the similarity of their relations with other agents and ontology alignments.

4.3.3 Capturing Agent-To-Agent Proximity Relationships

To capture relationships between agents, a model is defined based in four theories supported in literature:

1. Two actors with similar profiles have similar interests and a higher degree of proximity [Luz, 2010];
2. Two agents that have a similar relation with a determined element have a higher degree of proximity [Luz, 2010];
3. The more two agents interact with each other, the more their level of proximity increases (in interactions with positive outcomes) or decreases (in interactions with negative outcomes) [Yu and Wang, 2010];
4. The satisfaction of a consumer with the purchased product might give an indication of the supplier's service's quality [Jyun-Cheng and Chui-Chen, 2008].

Based on these, for each pair of agents the SN-i agent performs a set of evaluations in order to determine the existence and intensity of a relationship between them. The agent-to-agent relationship value (*atar*) is given by the weighted average of several factors:

$$atar(a,b) = \sum \left(w_i . f_i(a,b) \right) / \sum w_i \qquad (4)$$

Where *a* and *b* are the agents, f_i are the considered factors and w_i are the weights attributed to each one, which can be specified in the SN-i agent's configuration or can be calculated depending on the considered information for the factor in relation to the others.

The considered factors in this evaluation are:

- The similarity of their profiles and valued ontologies' entities (*pSim*);
- The success rate of their own previous negotiations (*srn*);

- The similarity of their interactions with other agents (*srnSim*);
- The satisfaction of B agent about the purchased products from S (*sat*).

Each of these will be addressed in the following subsections.

4.3.3.1 The Similarity of Users' Profiles and Valued Ontologies' Entities

The similarity of users' profiles and valued ontologies' entities is determined by comparing each common property from the users' profiles, and by comparing the agents' valued entities from common ontologies.

The method to calculate the similarity between properties will depend on their type. There are different types of properties that can be characterized by:

- The type of value – discrete (e.g. marital status) or continuous (e.g. age);
- The number of times they can be declared by an agent – functional (only once, e.g. gender) or non-functional (e.g. valued ontology's entity).

The similarity for continuous properties can be obtained by [Wu et al., 2007]:

$$cpSim(a,b,p) = 1 - \frac{|\mathrm{p}(a) - \mathrm{p}(b)|}{\max(p) - \min(p)} \tag{5}$$

Where *a* and *b* are the analyzed agents, *p* is the evaluated property, *p(a)* and *p(b)* are the values of the property *p* for agents *a* and *b* respectively, *max(p)* is the maximum limit for property *p* and *min(p)* is the minimum limit.

Following the same conventions, now with *p(a)* and *p(b)* representing the set of values of the property *p* for agents *a* and *b* respectively, the similarity value of a discrete functional property is given by [Luz, 2010]:

$$dfpSim(a,b,p) = \begin{cases} 1: |\mathrm{p}(a) \cap \mathrm{p}(b)| > 0 \\ 0 \text{ otherwise} \end{cases} \tag{6}$$

The similarity value of a non-functional discrete property is given by [Luz, 2010]:

$$dnfpSim(a,b,p) = \frac{|\mathrm{p}(a) \cap \mathrm{p}(b)|}{|\mathrm{p}(a) \cup \mathrm{p}(b)|} \tag{7}$$

The final value of this evaluation (*pSim*) is obtained by averaging all calculated values.

4.3.3.2 The Success Rate of the Previous Negotiations between the Agents

The success rate of the negotiations (*srn*) between agents *a* and *b* is given by:

$$srn(a,b) = \begin{cases} \dfrac{sn(a,b) - fn(a,b)}{tn(a,b)} : tn(a,b) > 0 \\ 0 : otherwise \end{cases} \tag{8}$$

Where *tn* is the total number of negotiations, *sn* is the number of successful negotiations and *fn* is the number of failed negotiations.

4.3.3.3 The Similarity of the Agents' Interactions with Other Agents

The similarity of the agents' interactions with other agents (*srnSim*) is given by:

$$srnSim(a,b) = Avg\big(srnS(a,b,c_i)\big) \tag{9}$$

Where c_i is any agent with previous negotiations with both *a* and *b*, and the absolute value of *srnS(a,b,ci)* is given by:

$$abs(srnS(a,b,c_i)) = \big|1 - |srn(a,c_i) - srn(b,c_i)|\big| \tag{10}$$

Here if $srn(a,c_i)$ and $srn(b,c_i)$ are both positive or both negative the final value of $srnS(a,b,c_i)$ is positive. Otherwise it is negative.

4.3.3.4 A Buyer's Satisfaction about the Purchased Products from a Seller

The satisfaction of a B agent (*a*) about the purchased products from a S agent (*b*) is given by:

$$sat(a,b) = Avg\left(sat\big(a,b,p_p,p_r\big)\right) \tag{11}$$

Where p_r is the desired product, p_p is the respective purchased product and $sat(a,b,p_p,p_r)$ is the satisfaction of agent *a*, about p_p considering p_r.

4.3.4 Determining Ontology Alignment's Adequacy to an Agent

The accuracy of the ontology alignment depends on many factors, including its semantics, granularity and coverage. Consequently, some agents achieve better business satisfaction using some alignments than using others. In the proposed approach it is assumed that:

- If the alignments are correct, then the more ontology's entities it contemplates (of the ones used by the agent), the higher will be the efficiency of the interactions;
- Some alignments may contain semantic errors, so it is necessary to evaluate the success rate of interactions involving them;
- A low satisfaction in closed deals may not be due to supplier's services' quality but in fact to the alignment's quality.

The alignment-to-agent adequacy (*ataa*) is given by the weighted average of several factors:

$$ataa(a,m) = \sum\big(w_i.f_i(a,m)\big)/\sum w_i \tag{12}$$

Where *a* is the agent, *m* is the alignment f_i are the considered factors and w_i are the weights attributed to each one, which can be specified in the SN-i agent's configuration or can be calculated depending on the considered information for the factor in relation to the others.

The considered factors in this evaluation are:

- The alignment's coverage of the agent's valued ontologies' entities (*cov*);
- The agent's success rate in business negotiations using the alignment (*srna*);
- The agent's satisfaction in closed deals using the ontology alignment (*sata*).

Each of these factors will be addressed in the following subsections.

4.3.4.1 The Alignment's Coverage of the Agent's Valued Ontologies' Entities

The alignment's (*m*) coverage in relation to an agent's (*a*) valued ontologies' entities is given by:

$$cov(a,m) = \frac{\sum w_i . cp_i - \sum w_j . ncp_j}{\sum w_i + \sum w_j} \tag{13}$$

Where:

- cp_i is an ontology's entity that is simultaneously valued by the agent and covered in the alignment;
- ncp_j is an ontology's entity that is valued by the agent but is not covered in the alignment;
- w_i and w_j are the weight assigned to the ontology's entities.

4.3.4.2 The Agent's Success Rate in Business Negotiations While Using the Alignment

The agent's success rate when using a specific alignment (m) is given by:

$$srna(a,m) = \begin{cases} \dfrac{sn(a,m) - fn(a,m)}{tn(a,m)} : tn(a,m) > 0 \\ 0 : otherwise \end{cases} \tag{14}$$

Where *tn* is the total number of the agent (*a*) business negotiations while using alignment *m*, *sn* is the number of successful negotiations using *m* and *fn* is the number of failed negotiations using *m*.

4.3.4.3 The Agent's Satisfaction in Closed Deals While Using the Alignment

The satisfaction of B agent (say *a*) about the purchased products when using alignment *m* is given by:

$$sata(a,m) = Avg\left(sata\big(a,m,p_r,p_p\big)\right) \tag{15}$$

Where p_r is the requested product, p_p is the purchased product, and $sata(a,m,p_r,p_p)$ measures the satisfaction in deals where *m* was used.

4.3.5 Determining Ontology Alignment's Adequacy to a Negotiation

When requested by the OM-i agent (or a business agent), the SN-i agent attributes a confidence value to an ontology alignment recommendation that indicates its confidence that the alignment is adequate to the business negotiation. This approach combines:

- A content-based recommendation technique (useful when there is no information about the alignments' previous usage);
- Concepts of trust-based recommendations (such as direct, indirect and global trust) [Das et al., 2011] using SNA.

The alignment-to-business-negotiation confidence (*atbc*) is given by the weighted average of several factors:

$$atbc(a, b, m, p_r) = \sum(w_i.f_i)/\sum w_i \tag{16}$$

Where *a* is the B agent, *b* is the S agent, *m* is the alignment under adequacy evaluation, p_r is the requested product description, f_i are the considered factors and w_i are the weights attributed to each one, which can be specified in the SN-i agent's configuration or can be calculated depending on the considered information for the factor in relation to the others. The considered factors in this evaluation are:

- The coverage of *m* according to the product description p_r (*mce*);
- The success rate in business negotiations while using the alignment (*sra*);
- The satisfaction in closed deals involving the alignment (*sa*);
- The adequacy of the alignment to B and S: *ataa(a,m)* and *ataa(b,m)*;
- The adequacy of the alignment to the agents closest to B and S: *rae(a,m)* and *rae(b,m)*.

Each of these factors will be addressed in the following subsections.

4.3.5.1 The Alignment's Coverage

The coverage of *m* according to the product description p_r (*mce*) is given by:

$$mce(pd, m) = \frac{|pc(p_r) \cap pc(m)|}{|pc(p_r) \cup pc(m)|} \tag{17}$$

Where $pc(p_r)$ is the set of ontology's entities used to describe the product, and *pc(m)* is the set of ontology's entities covered in the alignment.

4.3.5.2 The Success Rate in Business Negotiations while using the Alignment

The success rate in business negotiations while using the alignment (*sra*) is given by:

$$sra(m) = \begin{cases} \dfrac{sn(m) - fn(m)}{tn(m)} : tn(m) > 0 \\ 0 : otherwise \end{cases} \tag{18}$$

Where:

- $sn(m)$ is the number of successful business negotiations while using the alignment;

- $fn(m)$ is the number of failed business negotiations while using the alignment;
- $tn(m)$ is the total number of business negotiations where the alignment was used.

4.3.5.3 The Satisfaction in Closed Deals Involving the Alignment

The satisfaction in closed deals while using the alignment *m* is given by:

$$sa(m) = Avg\big(sata(\_, m, \_, \_)\big) \tag{19}$$

Where *sata(_,m,_,_)* is the satisfaction of any agent using *m* for any purchased product (cf. Section 4.3.4.3, Eq. 15).

4.3.5.4 The Adequacy of the Alignment to the Involved Agents

The adequacy of an alignment (*aa*) to a pair of agents (*a* and *b*) is obtained by averaging the values of the adequacy of the alignment to each agent:

$$aa(a, b, m) = Avg\big(ataa(a, m), ataa(b, m)\big) \tag{20}$$

Where *ataa(a,m)* and *ataa(b,m)* are obtained as previously defined (cf. Section 4.3.4, Eq. 12).

4.3.5.5 The Adequacy of the Alignment to the Agents Closest to the Involved Agents

The adequacy of the alignment (*m*) to the agents closest to an agent (*a*) is given by:

$$rae(a, m) = \frac{\sum atar(a, c_i) * ataa(c_i, m)}{\sum atar(a, c_i)} \tag{21}$$

Where c_i are the closest agents to *a*, i.e. those that have a high proximity relation with *a*, which can be related to *a* directly (there is a relation between *a* an c_i), or indirectly (when there is a multi-steps path from *a* to c_i). In the latter case the value of the relation from *a* to c_i is obtained by the accumulated product of each relation value in the path.

4.4 Final Remarks

This chapter presented the proposed model for the ontology services and the social network component.

The accuracy and adequacy of an ontology alignment is very important in e-commerce business negotiations. However, detecting semantically accurate and adequate alignments is not an easy task due to the different variables that may determine the success of the negotiation. For that, the SN-based component is introduced based on the assumption that taking into account captured emergent relationships between the agents and the overall usage of the ontology alignment, should result in a more accurate evaluation and usage of the ontology alignment, as well as a higher negotiation efficiency between negotiation partners.

The proposed SN is emergent and virtual, as opposite to an explicitly defined SN. The initial agents' proximity relations are based on their profile similarity and based on their ontologies' entities preferences, therefore this SN is relatively simple to capture and maintain.

5 Implementation and Results

5.1 Introduction

In order to validate the AEMOS proposed Model a new system was developed. The AEMOS system was developed in Open Agent Architecture (OAA) and Java. The OAA's Interagent Communication Language is the interface and communication language shared by all agents, and each agent is implemented in Java.

The model can be distributed over a network of computers, which is a very important advantage to increase simulation runs for scenarios with a large amount of agents.

5.2 AEMOS Interface

AEMOS system is very flexible as it is possible to define the model to simulate, including the number of agents, each agent's type, ontologies and strategies. For that, it was developed an application that can perform the configuration management.

By using the AEMOS's GUI, it is possible to configure and visualize the parameters of the scenario to simulate (e.g. Figure 19, Figure 20 and Figure 21, below).

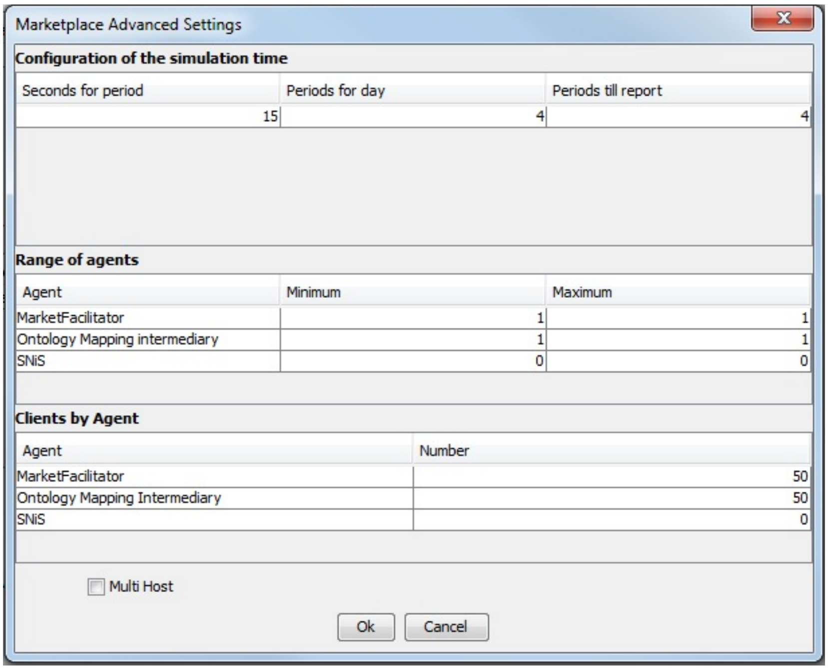

Figure 19 – AEMOS's GUI: Marketplace Advanced Settings

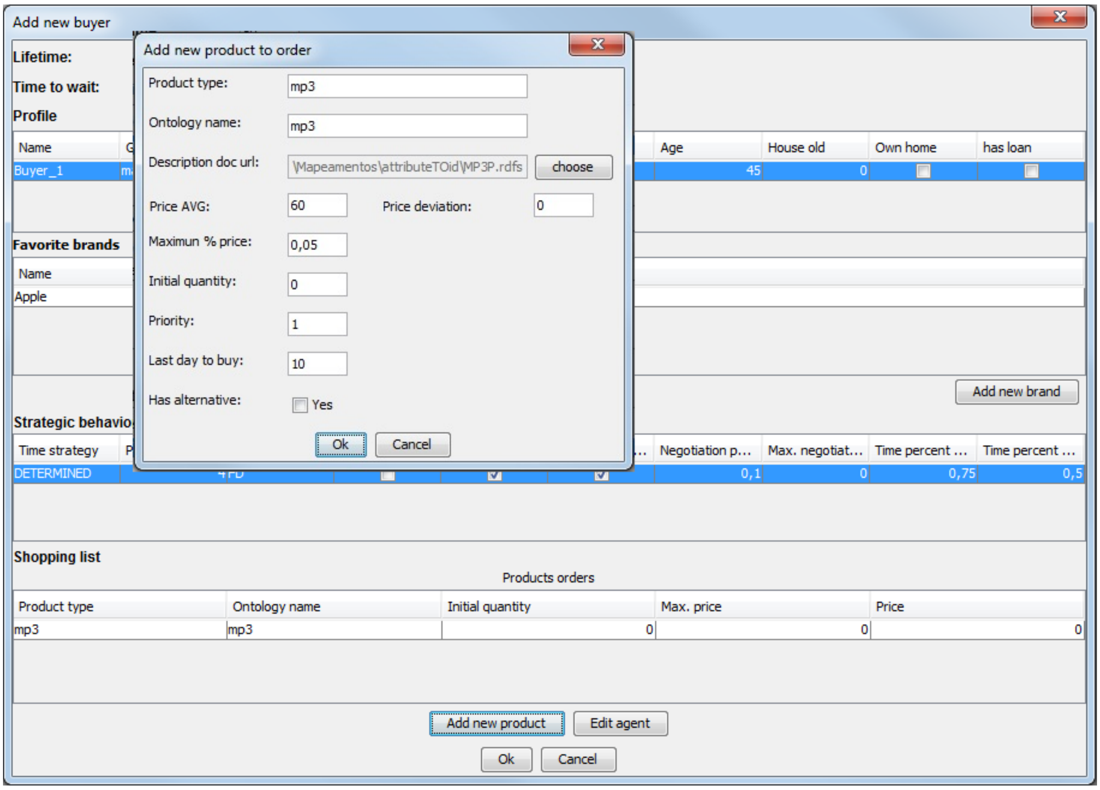

Figure 20 – AEMOS's GUI: A Buyer Agent's Configuration

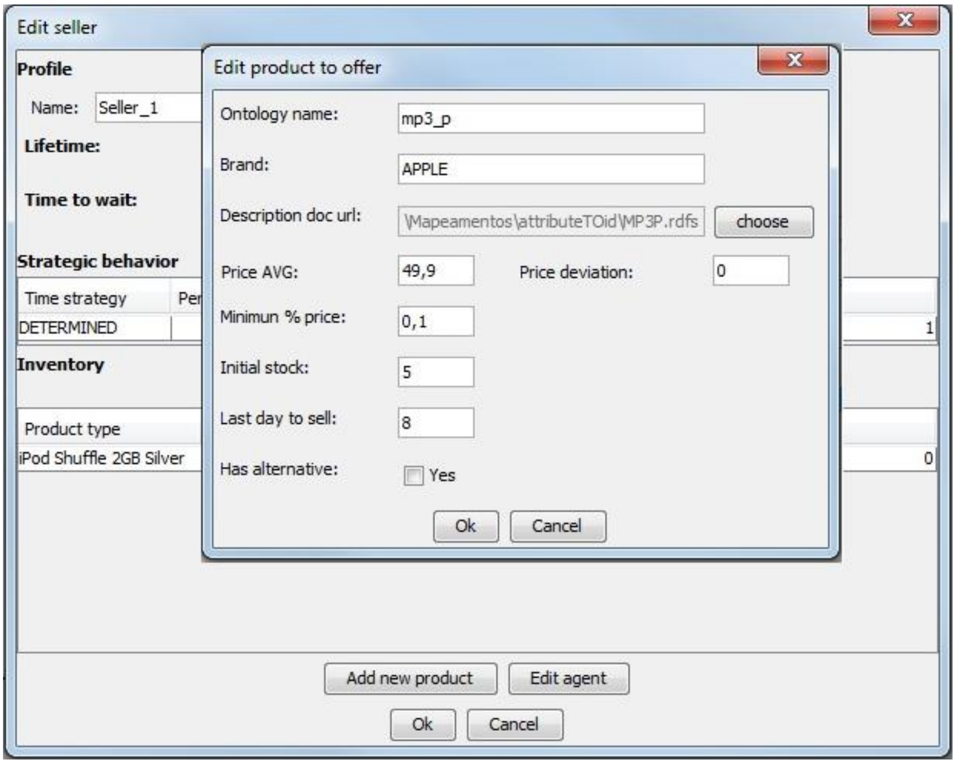

Figure 21 – AEMOS's GUI: A Seller Agent's Configuration

When the scenario is configured or selected the simulation can be initiated and its evolution observed (c.f. Figure 22 and Figure 23).

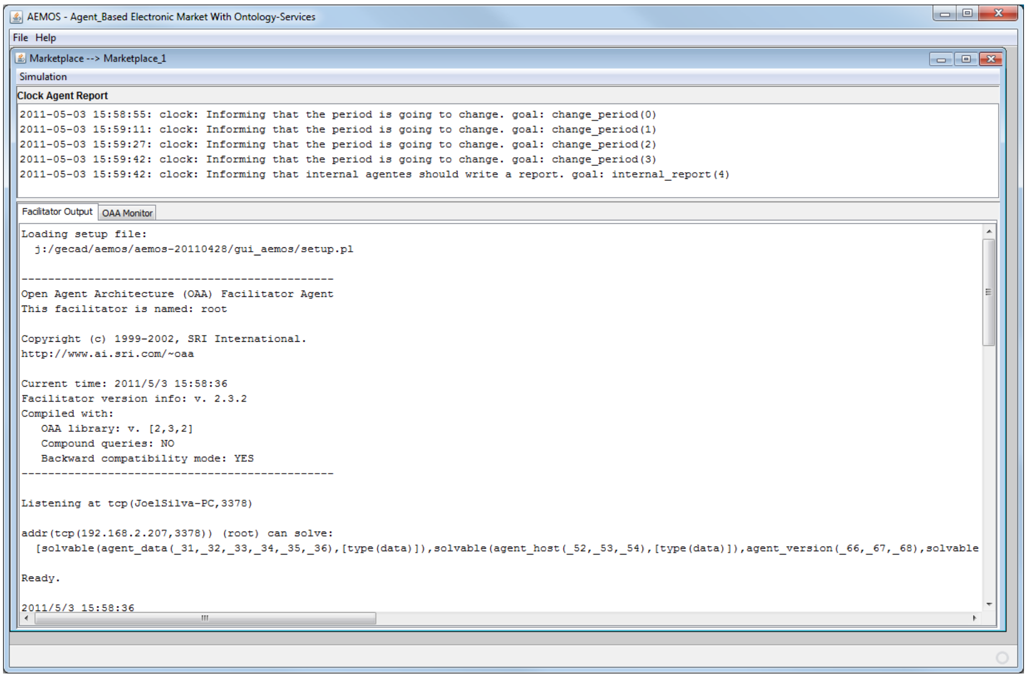

Figure 22 – AEMOS's GUI: Log of the OAA Facilitator and of the Clock Agent

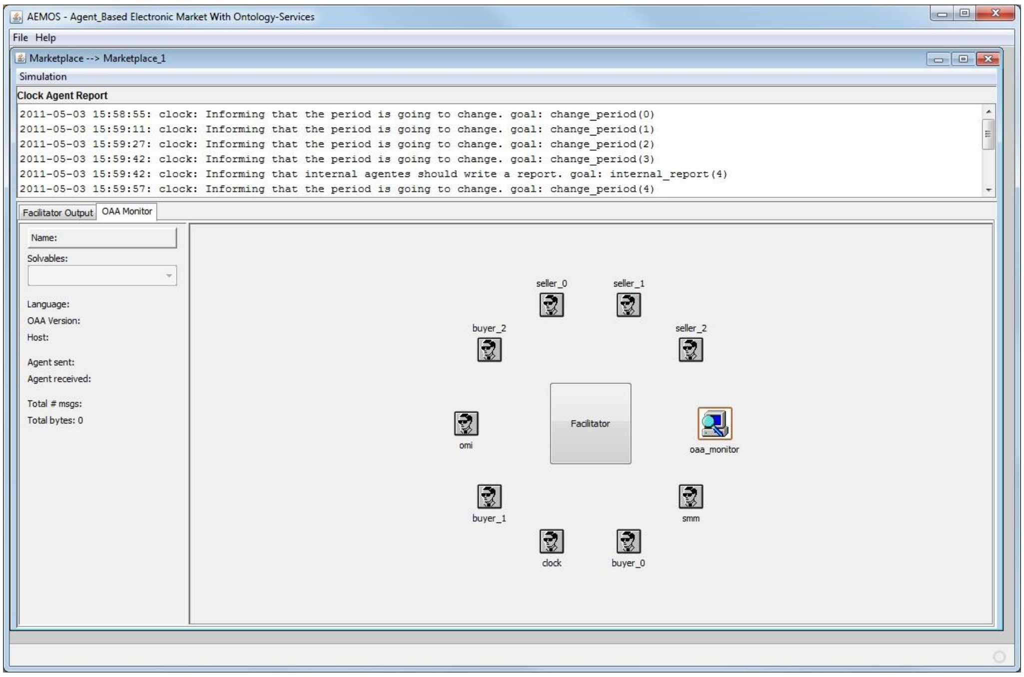

Figure 23 – AEMOS's GUI: The Marketplace Agents

5.3 A Case Study

In order to evaluate the AEMOS system and particularly respecting the relevance of the confidence value estimated by the SN-i agents to the ontology alignments, several experiments were performed.

It is intended to demonstrate, through a simplified scenario, how the SN-based component can improve the business negotiations' efficiency and enhance the average satisfaction with performed transactions, by reducing the selection of ontology alignments which are inadequate to each situation.

5.3.1 Consumers and Suppliers

A simple marketplace is considered, composed by 4 suppliers and 7 consumers, whose profiles are represented in Table 3 and Table 4 respectively.

Table 3 – Case Study: Seller Agents' Profiles

	S1	**S2**	**S3**	**S4**
Location	Lisbon, Madrid, Paris	Lisbon, Paris	Lisbon, London	London, Paris, Madrid
Represented Brands	Creative, Apple	Creative, Sony	Creative, Samsung	Creative, Apple

Table 4 – Case Study: Buyer Agents' Profiles

	B1	B2	B3	B4	B5	B6	B7
Gender	Female	Male	Female	Female	Male	Male	Male
Marital Status	Single	Single	Single	Married	Married	Single	Single
Location	Lisbon	Lisbon	London	Madrid	Madrid	London	Lisbon
Profession	Student	Professor	Student	Housewife	Controller	M.D.	M.D.
Income	Low	High	Low	Low	High	High	High
Age	19	30	18	42	42	55	45
Household	0	2	0	5	5	0	0
Owns House	No	Yes	No	Yes	Yes	Yes	Yes
Has Loans	No	Yes	No	Yes	Yes	Yes	Yes
Favorite Brands	Creative, Sony, Samsung	Creative, Apple, Sony	Creative, Apple, Sony	Creative, Apple	Creative, Apple	Apple	Apple, Sony

5.3.2 Ontologies and Ontology Alignments

As illustrated in Figure 24 and Figure 25 (cf. Section 5.3.3, below) three different ontologies are considered, namely:

- CEO[13] – Consumer Electronics Ontology, an ontology to describe electronic devices such as MP3 Players, TVs, Printers, among others; used by all S agents;
- MP3P[14] – MP3 Player, an ontology to describe audio devices; used by agents B1, B2, B3 and B4;
- SPDO[15] – Smart Product Description Ontology, a generic ontology to describe products; used by agents B5, B6 and B7.

This scenario ensures that the B and S agents always use different ontologies and, therefore, the satisfaction in deals will depend on the selected ontology alignment.

For each pair of ontologies, two alignments were developed: one semantically valid and another semantically incorrect. The first aligns all the concepts and properties which are correspondent between the ontologies, while the latter consider less of these correct correspondences and include some other which are incorrect.

The alignments are identified by the names of the involved ontologies in the format "<Source Ontology>To<Target Ontology>", for example, an alignment from the ontology CEO to the ontology MP3P will be denominated "CEOToMP3P". For the semantically incorrect alignments

[13] http://www.ebusiness-unibw.org/ontologies/consumerelectronics/v1
[14] http://daisy.cti.gr/svn/ontologies/AtracoProject/AtracoUserProfile/Y2Integration-FeelComfortable/MP3_Player.owl
[15] http://im.dm.hs-furtwangen.de/ontologies/spdo/2010b/SPDO.owl

it is added the suffix "_Bad", for example, the incorrect version of the mentioned alignment would be identified as "CEOToMP3P_Bad". These identifications are used in a later section of this chapter (cf. Section 5.4, Table 8 and Table 9).

5.3.3 Orders and Offers

In order to correctly evaluate the proposed model the agents will negotiate the same product: an audio device, with similar characteristics, and different ontologies are used in their shopping lists and inventories. Figure 24 and Figure 25 illustrate possible descriptions of the negotiating product according to different ontologies in orders and offers respectively.

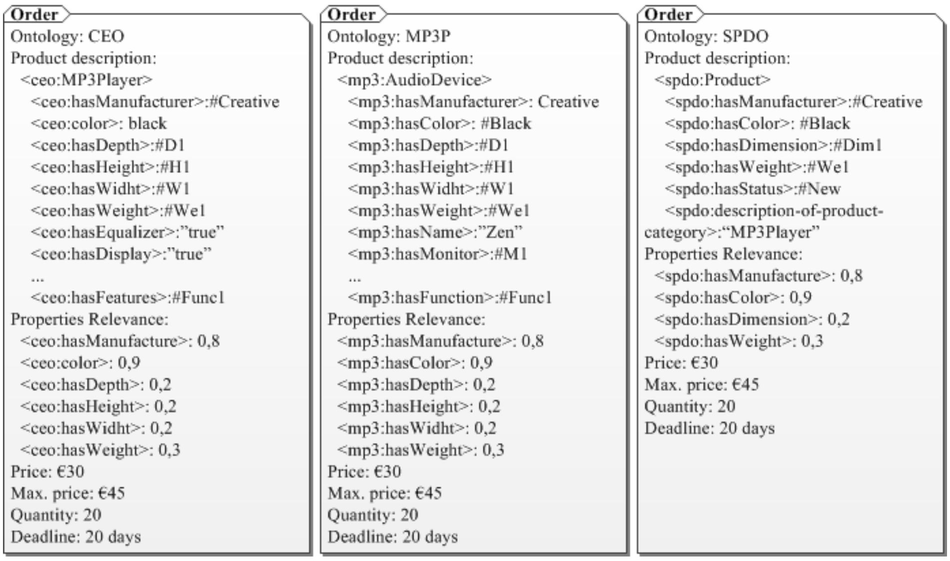

Figure 24 – Case Study: A Set of Orders for Buyer Agents

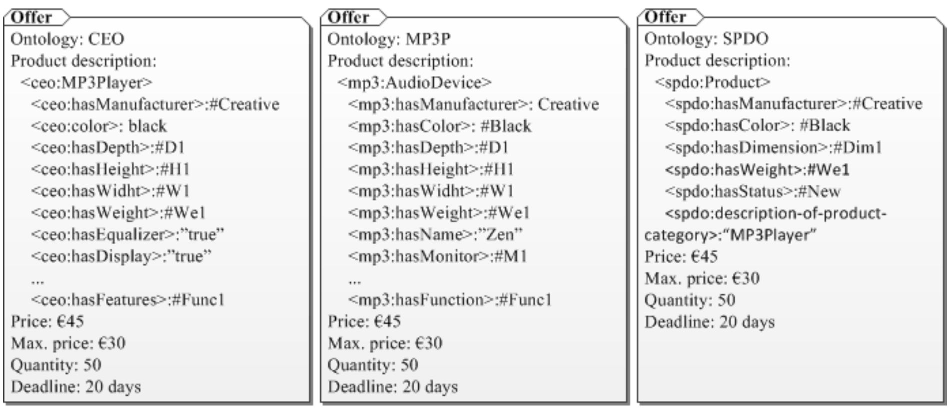

Figure 25 – Case Study: A Set of Offers for Seller Agents

Notice that the current experiment focus on the ontology dimension of the negotiation, so other relevant factors in the formulation/selection of a proposal (e.g. price, delivery time, quality of service) are considered to be similar and compatible for each agent.

5.3.4 Agents' Strategic Behavior

The business agents will follow the OM-i agent's recommendations about which ontology alignment to choose, filtering the alignments with a minimum score of 0.4, considering 10 as minimum number of negotiations for score credibility and declining or strengthen the given score 10% if the number of negotiations is too low.

5.3.5 SN-i Agent's Parameters

In this case study the SN-i agent weights its evaluation factors using the weight specified on its configuration. Since, in the current model, agents from the same type don't interact with each other, the relations between them should be based only on their profiles and actions similarity. The weights used by the SN-i agent in each of its evaluations are presented in the following tables.

Table 5 – Case Study: Agent-To-Agent Proximity Relationship Evaluation Factors Weights

Factor	***pSim***	***srnSim***	***srn***	***sat***
Weight for agents of different categories	0.30	0.20	0.25	0.25
Weight for agents of the same category	0.55	0.45	-	-

Table 6 – Case Study: Alignment-to-Agent Adequacy Evaluation Factors Weights

Factor	***cov***	***srna***	***sata***
Weight	0.30	0.40	0.30

Table 7 – Case Study: Alignment-to-Negotiation Adequacy Evaluation Factors Weights

Factor	***mce***	***sra***	***sa***	***ataa(a,m)***	***ataa(b,m)***	***rae(a,m)***	***rae(b,m)***
Weight	0.10	0.20	0.20	0.15	0.15	0.10	0.10

5.4 Scenarios and Results

Based on the previous set-up, two scenarios are proposed respecting the marketplace functionalities:

1. Where the SN-i agent's advice is followed: the OM-i agent consults the SN-i agent in order to decide which alignments to recommend;
2. Where the SN-i agent's advice is ignored: the OM-i agent analyses the ontology alignments taking into account the description of the requested product;

In the first scenario the SN-i agent starts building the initial relationship graph. Figure 26 illustrates the initial agents' relationship graph.

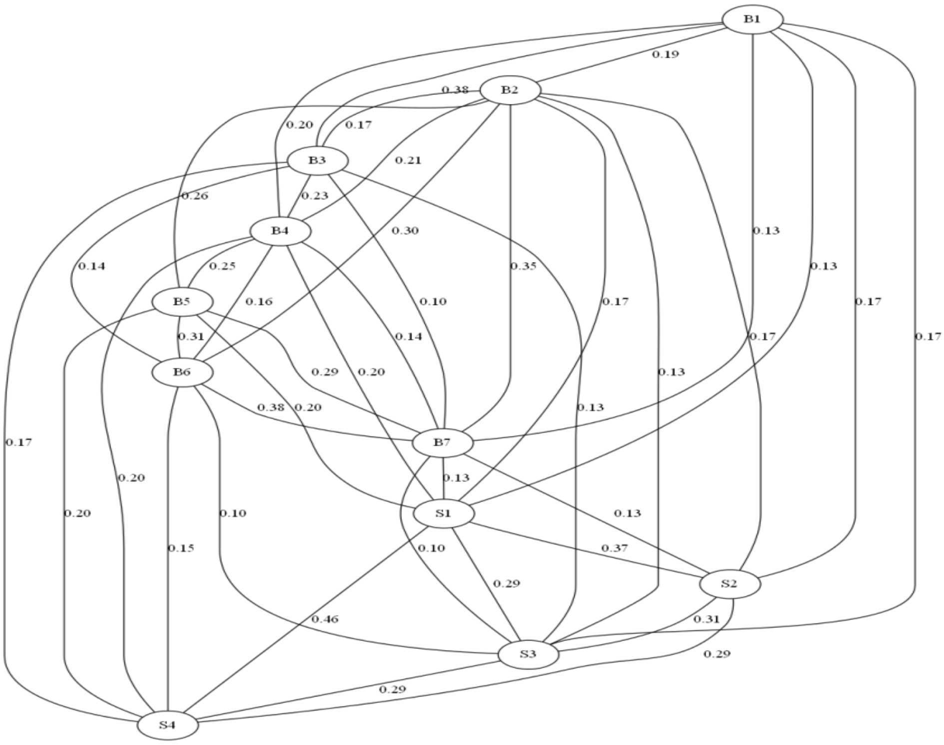

Figure 26 – Case Study: Initial Agents Relationships' Graph

The initial adequacy relations (*ataa*) between ontology alignments and agents are presented in Table 8.

Table 8 – Case Study: Initial Alignment-To-Agent Adequacy Relations

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**S1**	**S2**	**S3**	**S4**
CEOToMP3P	0.21	**0.21**	0.21	0.21	-	-	-	**0.03**	**0.03**	0.03	0.03
MP3PToCEO	0.19	**0.19**	0.19	0.19	-	-	-	**0.07**	**0.07**	0.07	0.07
CEOToMP3P_Bad	0.25	**0.25**	0.25	0.25	-	-	-	**0.17**	**0.17**	0.17	0.17
MP3PToCEO_Bad	0.24	**0.24**	0.24	0.24	-	-	-	**0.10**	**0.10**	0.10	0.10
MP3PToSPDO	0.16	**0.16**	0.16	0.16	0.28	0.28	0.28	-	-	-	-
SPDOToMP3P	0.13	**0.13**	0.13	0.13	0.27	0.27	0.27	-	-	-	-
MP3PToSPDO_Bad	0.06	**0.06**	0.06	0.06	0.13	0.13	0.13	-	-	-	-
SPDOToMP3P_Bad	-	-	-	-	0.28	0.28	0.28	-	-	-	-
CEOToSPDO	-	-	-	-	0.30	0.30	0.30	-0.07	-0.07	-0.07	-0.07
SPDOToCEO	-	-	-	-	0.28	0.28	0.28	-0.07	-0.07	-0.07	-0.07
CEOToSPDO_Bad	-	-	-	-	0.28	0.28	0.28	-0.07	-0.07	-0.07	-0.07
SPDOToCEO_Bad	-	-	-	-	0.28	0.28	0.28	-0.03	-0.03	-0.03	-0.03

In this scenario the agents using the same ontology describe the product in a similar way and have the same relevant attributes. Therefore, as demonstrated in Table 8 (above), their initial relations with ontology alignments will be identical (e.g. cf. agents S1 and S2 in Table 8, above).

During the market activity the SN-i agent updates this graph accordingly to the information it receives. Figure 27 illustrates the agents' relationships graph in a further point of the simulation.

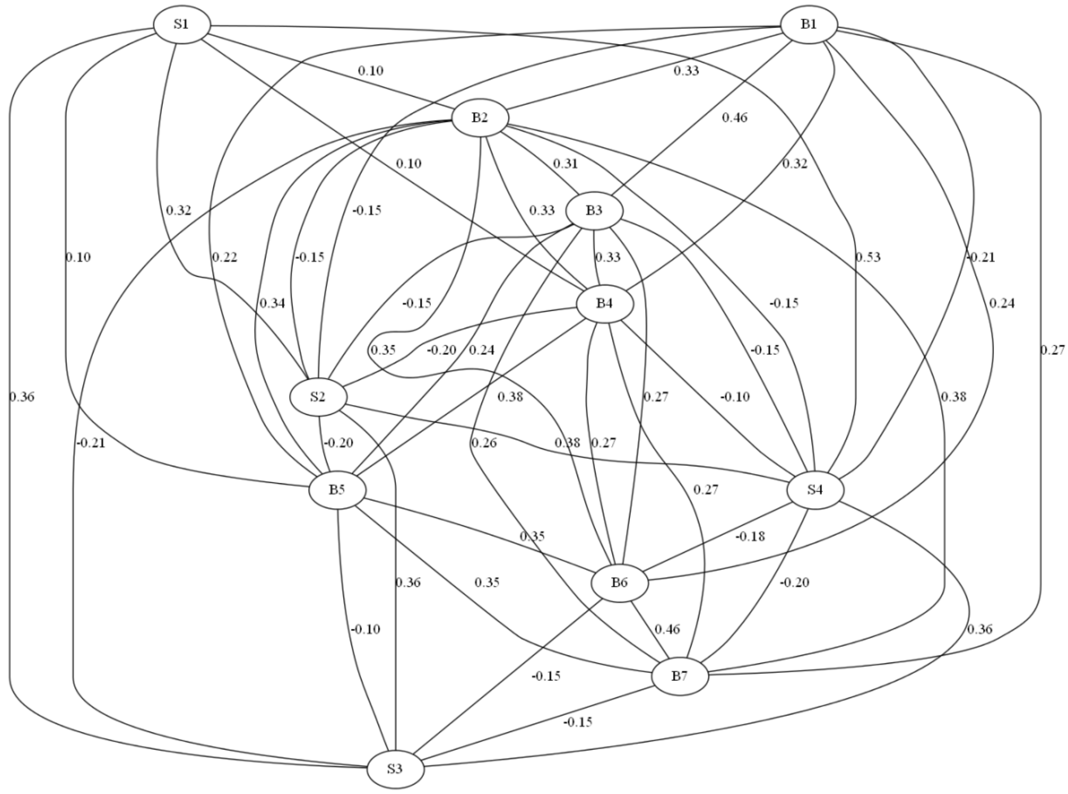

Figure 27 – Case Study: Updated Agents' Relationships Graph

The updated ontology alignment adequacy relations (*ataa*) are presented in Table 9 (below). As demonstrated, when the SN-i agent is used the ontology alignments' adequacy to the agents evolves during the simulation as they are used in more business negotiations (e.g., cf. B2 in Table 8 and Table 9).

Table 9 – Case Study: Updated Alignment-To-Agent Adequacy Relations

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**S1**	**S2**	**S3**	**S4**
CEOToMP3P	0.01	**0.05**	0.10	0.40	-	-	-	0.15	0.48	0.16	0.47
MP3PToCEO	0.02	**0.08**	0.22	0.17	-	-	-	0.21	0.42	0.10	0.41
CEOToMP3P_Bad	-0.03	**-0.06**	-0.14	-0.10	-	-	-	-0.06	-0.06	-0.06	-0.03
MP3PToCEO_Bad	-0.02	**0.02**	-0.06	-0.20	-	-	-	-0.19	-0.19	-0.19	-0.17
MP3PToSPDO	0.37	**0.36**	0.37	0.27	0.66	0.67	0.66	-	-	-	-
SPDOToMP3P	0.30	**0.27**	0.35	0.10	0.62	0.62	0.62	-	-	-	-
MP3PToSPDO_Bad	0.15	**0.10**	0.16	0.15	0.66	0.66	0.63	-	-	-	-
SPDOToMP3P_Bad	-	-	-	-	0.29	0.29	0.27	-	-	-	-
CEOToSPDO	-	-	-	-	0.08	0.09	0.10	0.23	0.31	0.40	0.59
SPDOToCEO	-	-	-	-	0.06	0.11	0.12	0.23	0.31	0.40	0.57
CEOToSPDO_Bad	-	-	-	-	-0.03	-0.02	-0.03	-0.53	-0.53	-0.53	-0.51
SPDOToCEO_Bad	-	-	-	-	-0.02	-0.03	-0.04	-0.53	-0.53	-0.53	-0.51

The presented scenarios ran several times in the AEMOS system. An illustration of the results between the two scenarios is captured in the following figures.

Figure 28 (below) allows comparing the relation between the adequacy of the used ontology alignment and the B agent's satisfaction in the achieved deal, in each of the two scenarios.

Figure 28 – Case Study: Relation between the Alignments' Adequacy and the Satisfaction in Deals in Each Scenario

As illustrated in Figure 28 (above) when the SN-i agent's advice is followed, normally, the adequacy of the chosen alignment is higher and so is the satisfaction of the B agent with the deals. This conclusion is also confirmed in Figure 29 (below) that shows that there is a higher average satisfaction in deals when the SN-i agent's advice is followed.

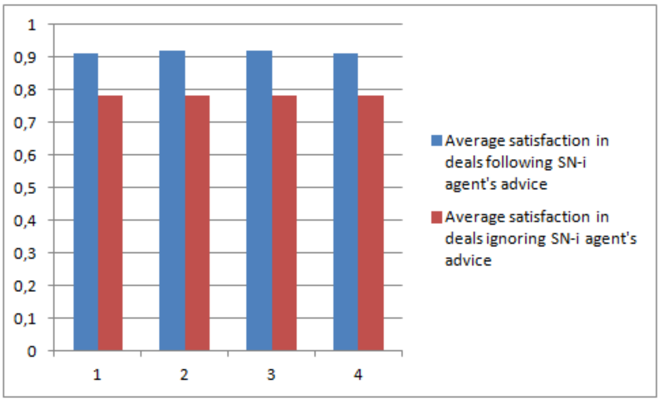

Figure 29 – Case Study: Average Satisfaction in Closed Deals for Each Scenario in the First Four Runs

Figure 30 and Figure 31 (below) analyze the number, and outcome, of business negotiations, comparing the results achieved in each scenario in multiple simulation runs.

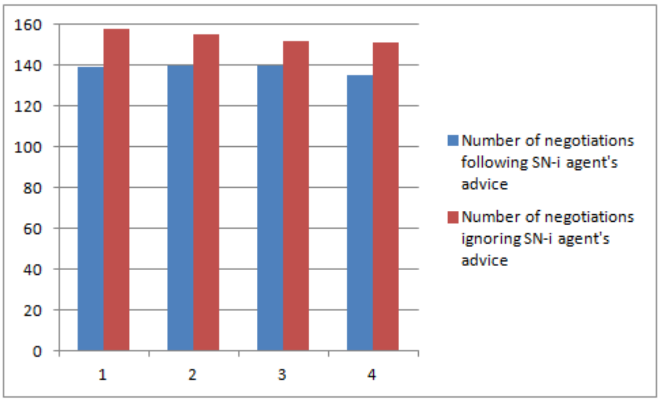

Figure 30 – Case Study: Number of Negotiations for Each Scenario in the First Four Runs

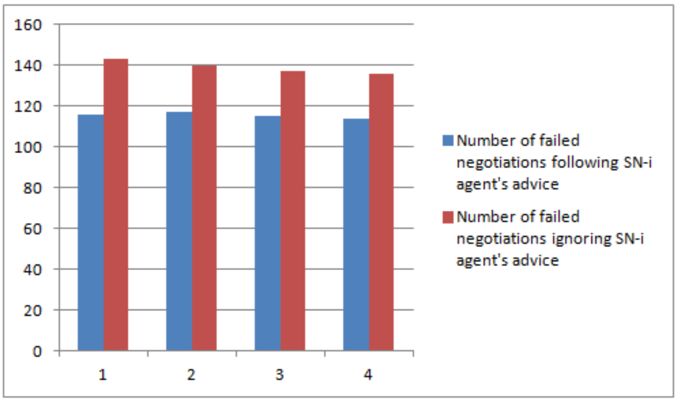

Figure 31 – Case Study: Number of Failed Negotiations for Each Scenario in the First Four Runs

As illustrated in this figures (Figure 30 and Figure 31, above), when the SN-i agent is ignored the agents need to negotiate more, as there are more failed negotiations. These results indicate that in this scenario the agents spend more time negotiating increasing the probability of reaching their deadlines and therefore transact fewer products. Figure 32 (below) confirms this suggestion illustrating the severe impact that the time spent in failed negotiations has on the achievement of their business goals.

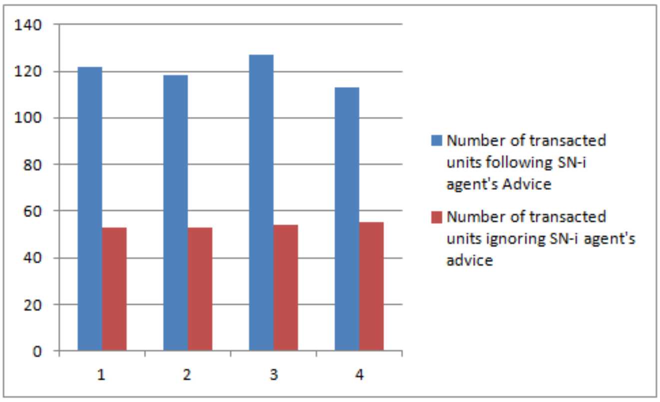

Figure 32 – Case Study: Number of Transacted Units for Each Scenario in the First Four Runs

The average results of the simulations are presented in the following table.

Table 10 – Case Study: Average Results of the Simulations

	Following SN-i agent	**Ignoring SN-i agent**
Average Satisfaction with Deals	0.917	0.781
Number of negotiations	138.5	154
Number of failed negotiations	115.5	139
Number of transacted Products	120	53.75

5.5 Final Remarks

As it can be observed in the previous results, when the SN-i agent's advice is ignored, the agents will continue choosing the inadequate alignments which will cause a severe impact on their business negotiations. Since there are more failed negotiations, the agents will have to spend more time negotiating until they are able to satisfy their business goals, increasing the probability of reaching their deadlines and not be able to transact all the products.

The experiments indicate that when the SN component is included in the system, the achieved results are highly improved:

1. There is a higher satisfaction in closed deals;
2. The agents need to negotiate less to satisfy their business goals;
3. There are less failed negotiations; and,
4. There are more transacted products.

These results validate the models presented in the previous chapters, suggesting that a SN component can highly improve the business negotiations efficiency.

6 Conclusions and Future Work

6.1 Conclusions

This work proposes an agent-based e-commerce platform that provides ontology services, including the recommendation of possible ontology alignments between the negotiation agents' ontologies.

Due to its natural ambiguity and subjectivity, the ontologies matching process can lead to different alignments that may affect the negotiation efficiency. The accuracy and adequacy of an ontology alignment is very important in e-commerce business negotiations. However, detecting semantically accurate and adequate alignments is not an easy task due to the different variables that may determine the success of the negotiation.

The model proposed in this thesis is based on the assumption that by considering the usage of the alignment in previous negotiations, and by analyzing the overall interactions between agents, it is possible to capture the adequacy of the alignment to a negotiation.

The proposed SN is emergent and virtual, as opposite to an explicitly defined SN. The initial agents' proximity relations are based on their profile similarity and based on their ontologies' entities preferences, therefore this SN is relatively simple to capture and maintain. Nevertheless, as shown in the experimentation results, it is very effective, as it allows the SN-i agent to progressively recommend the most adequate ontology alignments to the agents in a specific negotiation.

For business agents, the choice of the method used to evaluate recommended ontology alignments, would depend on its demand and confidence in the system. Since it is expected that the recommendations proposed by the system are increasingly better over time, with consequent better results, by agents, it is expected that the confidence of the agent in the system also improves.

This project was developed in the e-commerce context and for business negotiations. However the developed multi-agent model can be applied in other negotiation contexts such as coalition formation or virtual enterprise creation.

The Ontology Services model can also be applied in any MAS, in fact, the OM-i agent itself can be included in any MAS (developed in OAA), without the need for any modification. The same applies for the SN-i agent and the SN-based support model.

The majority of the presented suggestions has been considered not only for the future development of this thesis work, but also as basis for several new projects, namely the Multi-Agent Negotiation for Ontology Mapping – NegOntMap (PTDC/EIA-EIA/116799/2010) and the Negotiation Based on Argumentation for Ontology Mapping – ARGOM (PTDC/EEI-SII/2445/2012).

Concluding, this work has proven to be highly successful, as supported by the achieved results and enhanced by the scientific publications it has originated.

6.2 Open Issues and Future Work

Despite the described experiments demonstrate the usefulness of the model and of the proposed implementation, being successful in the fulfilling of the initial goals there are some aspects in the systems which can be improved and future research directions can be referred.

Currently, the object of negotiation, during the ontology alignment negotiation, is the ontology alignment document, i.e., the set of correspondences between the concepts and properties of the ontologies. It is defended though [Silva et al., 2009] that negotiating alignment for each ontology concept separately could result in more complete and adequate ontology alignments which would contain the correspondences with highest score, being tested and improved as they are applied during business negotiations.

A limitation of the current system is the fact that when agents use ontologies which are not recognized by the system they can only negotiate with agents that used the same ontologies. This problem could be attenuated by including a component that would collect information about new ontologies and perform, automatically, alignments for these ontologies. In this case, the limitations of the automatic ontology alignment technologies could be attenuated if the previous feature is already implemented.

AEMOS consumer behavior is modeled according to de CBB model. However, not all the phases from this model are contemplated. It would be interesting to introduce the Buyer Coalition formation phase in the model, applying the developed negotiation protocols, ontology services and social network support models in this new phase, where the trust between the negotiation partners plays an important role (e.g. in the election of the coalition leader).

During the activity of the market the SN-i agent captures relationships between the business agents. This information could be important for a business agent to decide if it should initiate a negotiation with a proposed partner, or even to evaluate proposals formulated by a determined agent.

Experimentation demonstrated that the SN-i agent model is efficient, however it adopts only simplified measures essentially based in the homophily and transitivity concepts. This model could be significantly improved, exploiting other SNA techniques, in other to achieve a more sophisticated model.

References

[Ateib, 2010] Ateib, M. T., 2010. *Agent Based Negotiation In E-commerce.* s.l.:IEEE computer society.

[Bakos, 1998] Bakos, Y., 1998. Towards Friction-Free Markets: The Emerging Role of Electronic Marketplaces on the Internet. *Communications of the ACEM,* 41(8), pp. 35-42.

[Bellifemine et al., 2003] Bellifemine, F., Caire, G., Poggi, A. & Rimassa, G., 2003. *JADE A White Paper.* [Online]
Available at:
http://jade.tilab.com/papers/2003/WhitePaperJADEEXP.pdf
[Last Accessed in October 2012].

[Brost, 1997] Brost, W. N., 1997. *Construction of Engineering Ontologies for knowledge Sharing and Reuse,* s.l.: s.n.

[Cao et al., 2009] Cao, M., Feng, Y. & Liu, Z., 2009. E-Commerce Oriented Negotiating Agent Communication Model. In: *Proc. Of the 42nd Hawaii International Conference on System Sciences.* s.l., s.n.

[Cui-Mei, 2009] Cui-Mei, B., 2009. Combining Intelligent Agent with the Semantic Web Services for Building An e-Commerce System. In: *2009 IEEE International Conference on e-Business Engineering* s.l., IEEE computer society.

[Das et al., 2011] Das, A., Islam, M. M. & Sorwar, G., 2011. *Dynamic Trust Model for Reliable Transactions in Multi-agent Systems.* s.l., s.n.

[Davis, 1980] Davis, R., 1980. Report on the Workshop on Distributed Artificial Intelligence. *SIGART Newsletter*, October, Volume 73, pp. 42-52.

[Du et al., 2005] Du, T. C., Li, E. Y. & Chou, D., 2005. Dynamic vehicle routing for online B2C delivery. In: s.l.:Omega, pp. 33-45.

[Elamy, 2005] Elamy, A., 2005. Perspectives in agent-based technology. *AgentLink News,* Volume 18, pp. 19-22.

[Euzenat and Shvaiko, 2007] Euzenat, J. & Shvaiko, P., 2007. *Ontology matching.* s.l.:Springer.

[Fensel et al., 2001] Fensel, D. et al., 2001. Product Data Integration in B2B E-Commerce. *IEEE Intelligent Systems 16.* s.l., s.n., pp. 54-59.

[FIPA, 1996] FIPA, 1996. *Foundation for Intelligent Physical Agents.* [Online]
Available at: http://www.fipa.org/
[Last Accessed in September 2012].

[FIPA, 2001] FIPA, 2001. *FIPA Ontology Service Specification.* [Online]
Available at: http://www.fipa.org/specs/fipa00086/
[Last Accessed in September 2012].

[FIPA, 2002a] FIPA, 2002. *FIPA-ACL.* [Online]
Available at: http://www.fipa.org/specs/fipa00070/
[Last Accessed in September 2012].

[FIPA, 2002b] FIPA, 2002. *FIPA Iterated Contract Net Interaction Protocol Specification.* [Online]
Available at: http://www.fipa.org/specs/fipa00030/
[Last Accessed in September 2012].

[Gruber, 1993] Gruber, T., 1993. A translation approach to portable ontology specifications. In: *Knowledge Acquisition.* s.l.:s.n., pp. 199-220.

[Handcock et al., 2007] Handcock, M., Raftery, A. & Tantrum, J., 2007. Model-based clustering for social networks. *Journal of the Royal Statistical Society: Series A (Statistics in Society).*

[Hannerman and Riddle, 2005] Hannerman, R. A. & Riddle, M., 2005. *Introduction to social network methods.* Riverside, CA: University of California.

[He et al., 2003] He, M., Jennings, N. R. & Leung, H.-F., 2003. On Agent-Mediated Electronic Commerce. *IEEE Transactions on Knowledge and Data Engineering.* s.l., IEEE Computer Society.

[Hepp, 2008] Hepp, M., 2008. GoodRelations: An Ontology for Describing Products and Services Offers on the Web. In: *Proc. Of the 16th International Conference on Knowledge Engineering and Knowledge Management (EKAW2008).* s.l., Springer LNCS, pp. 332-347.

[Huang et al., 2009] Huang, C.-C., Liang, W.-Y., Lai, Y.-H. & Lin, Y.-C., 2009. The agent-based negotiation process for B2C e-commerce. *Expert Systems with Applications,* Volume 37, pp. 348-359.

[Huang et al., 2010] Huang, W., Jin, J., Wang, N. & Wang, F., 2010. Technology and Application of Intelligent Agent in Electronic Commerce. In: *2010 International Conference on Measuring Technology and Mechatromics Automation.* s.l., IEEE computer society.

[Hu et al., 2008] Hu, J., Wu, Q. & Zhou, B., 2008. FCTrust: A Robust and Efficient Feedback Credibility-Based Distributed P2P Trust Model. In: *Proceedings of IEEE 9th International Conference for Young Computer Scientists (ICYCS).* s.l., IEEE Computer Soc. Press, p. 1963–1968.

[JADE, 2000] JADE, 2000. *JADE.* [Online]
Available at: http://jade.tilab.com/
[Last Accessed in September 2012].

[Java, 1995] Java, 1995. *Java.* [Online]
Available at: http://www.java.com
[Last Accessed in September 2012].

[Jennings et al., 2001] Jennings, N. et al., 2001. Automated negotiation: prospects, methods and challenges. In: *Int. J. of Group Decision and Negotiation.* s.l., s.n., pp. 199-215.

[Jyun-Cheng and Chui-Chen, 2008] Jyun-Cheng, W. & Chui-Chen, C., 2008. Recommending trusted online auction sellers using social network analysis. *Expert Systems with Applications,* Volume 34, pp. 1666-1679.

[Klein, 1994] Klein, S. L. T., 1994. Electronic Markets: An Introdution. In: *International Conference in Information and Communications Technologies in Tourism.* Innsbruck, Austria, s.n.

[Krovi et al., 1999] Krovi, R., Graesser, A. C. & Pracht, W. E., 1999. Agent Behaviours in Virtual Negotiation Environments. In: *IEEE Transactions on Systems, Man, and Cybernetics – Part C: Applications and Review.* s.l.:s.n., pp. 15-25.

[Laudon and Laudon, 2000] Laudon, K. C. & Laudon, J. P., 2000. *Management information systems.* 6th ed. London: Prentice-Hall.

[Li et al., 2008] Li, B., Xing, M., Zhu, J. & Che, T., 2008. A Dynamic Trust Model for the Multi-agent Systems. In: *Proceedings of IEEE International Symposiums on Information Processing (ISIP).* s.l., IEEE Computer Soc. Press, pp. 500-504.

[Lomuscio et al., 2001] Lomuscio, A., Wooldridge, M. & Jennings, N., 2001. A Classification Scheme for Negotiation in Electronic Commerce. In: F. Dignum & C. Sierra, edits. *Agent Mediated Electronic Commerce, European AgentLink Perspective, Lecture Notes in Artificial Intelligence 1991.* s.l.:Springer, pp. 19-33.

[Luz, 2010] Luz, N., 2010. *Semantic Social Network Analysis,* Porto, Portugal: s.n.

[Maedche et al., 2002] Maedche, A., Motik, B., Silva, N. & Volz, R., 2002. MAFRA - A Mapping Framework for Distributed Ontologies in the Semantic Web. In: *EKAW '02 Proceedings of the 13th International Conference on Knowledge Engineering and Knowledge Management. Ontologies and the Semantic Web.* London, UK, Springer-Verlag, pp. 235-250.

[Martins, 2008] Martins, H., 2008. *Ontology Mapping Evolution,* Porto, Portugal: s.n.

[Mei et al., 2009] Mei, P. Q., Hong, Z., Cun, C. Y. & Qin, P. X., 2009. An E-negotiation Model Based on Multi-agent and Ontology. In: *2009 International Conference on Computational Intelligence and Natural Computing.* s.l., s.n., pp. 107-110.

[Mohanty and Passi, 2010] Mohanty, B. & Passi, K., 2010. Agent based e-commerce systems that react to buyers' feedbacks - A fuzzy approach. *International Journal of Approximate Reasoning,* Volume 51, pp. 948-963.

[Nascimento et al., 2012] Nascimento, V., Viamonte, M. J., Canito, A. & Silva, N., 2012. Enhancing ontology alignment recommendation by exploiting emergent social networks. In: *The 2012 IEEE/WIC/ACM International Conference on Intelligent Agent Technology.* Macau, s.n.

[OAA, s.d.] OAA, s.d. *OAA.* [Online]
Available at: http://www.ai.sri.com/~oaa/
[Last Accessed in September 2012].

[Obrst et al., 2003] Obrst, L., Liu, H. & Wray, R., 2003. Ontologies for Corporate Web Applications. *AI Magazine*, September, 24(3), pp. 49-62.

[Qin et al., 2009] Qin, P. X., Mei, P. Q. & Young, L., 2009. Using Ontology into Dynamic Electronic Negotiation Process. In: *2009 Third International Conference on Genetic and Evolutionary Computing.* s.l., s.n.

[Runyon and Stewart, 1987] Runyon, K. & Stewart, D., 1987. *Consumer Behavior.* 3rd ed. s.l.:Merrill Publishing Company.

[Saad et al., 2008] Saad, S., Zgaya, H. & Hammadi, S., 2008. *Using an Ontology to Solve the Negotiation Problems in Mobile Agent Information System,* Villeneuve d'Ascq, France: s.n.

[Sandholm and Vulkan, 1999] Sandholm, T. & Vulkan, N., 1999. Bargaining with Deadlines. In*: Proceedings of the National Conference on Artificial Intelligence (AAAI).* Orlando, Florida USA, s.n., pp. 44-51.

[Schmid, 1994] Schmid, B., 1994. Electronic Markets on Tourism. In: *International Conference in Information and Communications Technologies in Tourism.* Innsbruck, Austria, s.n.

[Scott, 1991] Scott, J., 1991. *Social Network Analysis: A Handbook.* Newbury Park, CA: Sage Publications.

[Silva et al., 2009] Silva, N., Viamonte, M. J. & Maio, P., 2009. Agent-Based Electronic Market With Ontology-Services. *In: 2009 IEEE International Conference on e-Business Engineering.* Macau, s.n.

[Studer et al., 1998] Studer, R., Richard, B. V. & Fensel, D., 1998. Knowledge engineering: principles and methods. In: *Data Knowledge Engineering.* s.l.:s.n., pp. 161-197.

[Till, 1998] Till, R., 1998. Transforming the Way We Do Business. In: T. Nash, ed. *Electronic Commerce.* s.l.:s.n., pp. 9-12.

[Varian, 1980] Varian, H., 1980. A Model of Sales. *American Economic Review, Papers and Proceedings,* 70(4), pp. 651-659.

[Viamonte, 2004] Viamonte, M. J., 2004. *Mercados Electrónicos Baseados em Agentes - Uma Abordagem Orientada ao Conhecimento Considerando Estratégias Dinâmicas,* Vila Real, Portugal: s.n.

[Viamonte et al., 2012] Viamonte, M. J., Nascimento, V., Silva, N. & Maio, P., 2012. AEMOS: An Agent-Based Electronic Market Simulator With Ontology-Services And Social Network Support. *In: The 24th European Modeling & Simulation Symposium (Simulation in Industry).* Viena, Austria, s.n.

[Viamonte et al., 2006] Viamonte, M. J., Ramos, C., Rodrigues, F. & Cardoso, J., 2006. ISEM: A Multi-Agent Simulator For Testing Agent Market Strategies. *IEEE Transactions on Systems, Man and Cybernetics – Part C: Special Issue on Game-theoretic Analysis and Stochastic Simulation of Negotiation Agents*, 36(1), pp. 107-113.

[Viamonte et al., 2011] Viamonte, M. J., Silva, N. & Maio, P., 2011. Agent-Based Simulation of Electronic Marketplaces With Ontology-Services. In: *The 23rd European Modeling & Simulation Symposium (Simulation in Industry).* Rome, Italy, s.n.

[Wang and Wang, 2008] Wang, X. & Wang, L., 2008. P2P Recommendation Trust Model. In: *Proceedings of IEEE 8th International Conference on Intelligent Systems Design and Applications (ISDA).* s.l., IEEE Computer Soc. Press, pp. 591-595.

[Wasserman and Faust, 1994] Wasserman, S. & Faust, K., 1994. *Social Network Analysis: Methods and Applications (Structural Analysis in the Social Sciences).* Cambrige: Cambrige University Press.

[Weiss, 2010] Weiss, G., 2010. *Multiagent Systems: a modern approach to distributed artificial intelligence.* s.l.:MIT Press.

[Wen et al., 2009] Wen, L., Lingdi, P., Kuijin, L. & Xiaoping, C., 2009. Trust model of Users' behavior in Trustworthy Internet. In: *Proceedings of IEEE WASE International Conference on Information Engineering (ICIE).* s.l., IEEE Computer Soc. Press, pp. 403-206.

[Wooldridge, 2002] Wooldridge, M., 2002. *An introduction to multiagent systems.* s.l.:John Wiley & Sons Ltd..

[Wu et al., 2007] Wu, B., Pei, X., Tan, J. & Wang, Y., 2007. Resume Mining of Communities in Social Network. In: *Seventh IEEE International Conference on Data Mining Workshops (ICDMW 2007).* Omaha, NE, USA, s.n., pp. 435-440.

[Xiao-fang and Ying, 2006] Xiao-fang, C. & Ying, W., 2006. *Model of Multi-Agent Based on Personalized Transactions in Electronic Commerce.* s.l., s.n.

[Xiong and Li, 2004] Xiong, L. & Li, L., 2004. PeerTrust: Supporting Reputation-Based Trust for Peer-to-Peer Electronic Communities. *IEEE Transactions on Knowledge and Data Engineering,* Volume 16, p. 843–857.

[Yeh and Wu, 2010] Yeh, J.-h. & Wu, M.-l., 2010. Recommendation Based on Latent Topics and Social Network Analysis. In: *2010 Second Interantional Conference on Computer Engineering and Applications.* s.l., s.n.

[Yu and Wang, 2010] Yu, X. & Wang, Z., 2010. *A Enhanced Trust Model Based on Social Network and Online Behavior Analysis for Recommendation.* s.l., s.n.

[Zhang et al., 2011] Zhang, L., Song, H., Chen, X. & Hong, L., 2011. A simultaneous multi-issue negotiation through autonomous agents. *European Journal of Operational Research,* Volume 210, pp. 95-105.

[Zhang et al., 2009] Zhang, Y., Chen, S. & Yang, G., 2009. SFTrust: A double Trust Metric Based Trust Model in Unstructured P2P Systems. In: *Proceedings of IEEE International Symposium on Parallel and Distributed Processing (ISPDP).* s.l., IEEE Computer Soc. Press, pp. 1-7.

[Zhou, 2009] Zhou, L., 2009. *Trust Based Recommendation System with Social Network Analysis.* s.l., s.n.

Annex A – System Management Agents

In AEMOS there is a group of supporting agents responsible for the system's management granting its dynamism, flexibility and correct functioning. Here, four of their main functions are highlighted, being each one the responsibility of a given type of agent:

- Controlling the system's agents – achieved by the Market Manager agent;
- Expanding the system dynamically – achieved by the Market Extension Manager agent;
- Centralizing the market's information – achieved by the Market Data Manager agent;
- Simulating time evolution and managing periodic events – achieved by the Clock agent.

Controlling System's Agents (Market Manager Agent)

The Market Manager (MM) agent manages all supporting agents, registers business agents and manages agents' associations.

When initialized this agent starts all supporting agents accordingly to its configuration, performing the initial agents' associations (i.e. associate OM-i agents to MF agents, and SN-i agents to OM-i agents).

When a business agent registers on the market, the MM checks the current system capacity and, if necessary and allowed, initializes new supporting agents in order to be associated with the new registered agent.

During the registration of the business agent, the MM agent ensures that the provided information is stored by the appropriate agents namely, MDM, SN-i and MF agents.

Expanding the System Dynamically (Market Extension Manager Agent)

The Market Extension Manager (MEM) agent is an optional agent that aids the MM agent with its functions. This agent allows the addition of machines to the system where supporting agents can be initialized dynamically.

When the MM agent decides that the machine where it is executing its reaching its full capacity and it needs to initiate a new supporting agent, if there is this possibility, it will request an MEM agent to initiate the supporting agent.

Centralizing Market Information (Market Data Manager Agent)

The Market Data Manager (MDM) agent registers information about all business agents participating in the market. When a business agent registers in the market, or notifies that is leaving, the provided information is stored by this agent.

This agent is responsible to provide market information to other agents, and for writing statistical reports that enable validating the correct functioning of the market.

Simulating Time Evolution and Managing Periodic Events (Clock Agent)

The Clock agent is a component originally introduced in the ISEM simulator to facilitate the utilization of the OAA platform in a simulation system, given that this platform is not specially designed for this type of systems.

The Clock agent is responsible to simulate the evolution of time, alerting the other agents about relevant points in time.

This agent is also capable of scheduling periodic actions, notifying the appropriate agents about these events.